WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

Annually 35 shillings by post. Single Copies 2s. 6d.

Volume 6. Number 6.

CONTENTS FOR JUNE, 1954

Editorial: Electrical Problems - - - 203

Editorial Notes - - - - - 204

Owen Falls—I - - - - - 206

Book Reviews - - - - - - 216

Criticism of Elutriation Systems for the Treatment of Sand for Concrete - - - - - 217
By Dr. Th. Eder, Vienna

The Salanfe - Miéville Turbines - - - 221
By Paul Pingoud, Ing.Dipl. (Lausanne)

Model Technique for the Solution of Water - Hammer Problems - - - - - - 226
By D. W. Kingdon, B.Sc. (Eng.), A.M.I.Mech.E.

Hydro - Electricity and Fish - - - - 230

India's Bhakra - Nangal Project—II - - - 232

Short Articles: Holman Silver Three Handril — G.E.C. 33 kV On-Load Tapping Switch — Errochty Alternator - - - - - - 238

Abstracts from the World Technical Press - - 240

Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

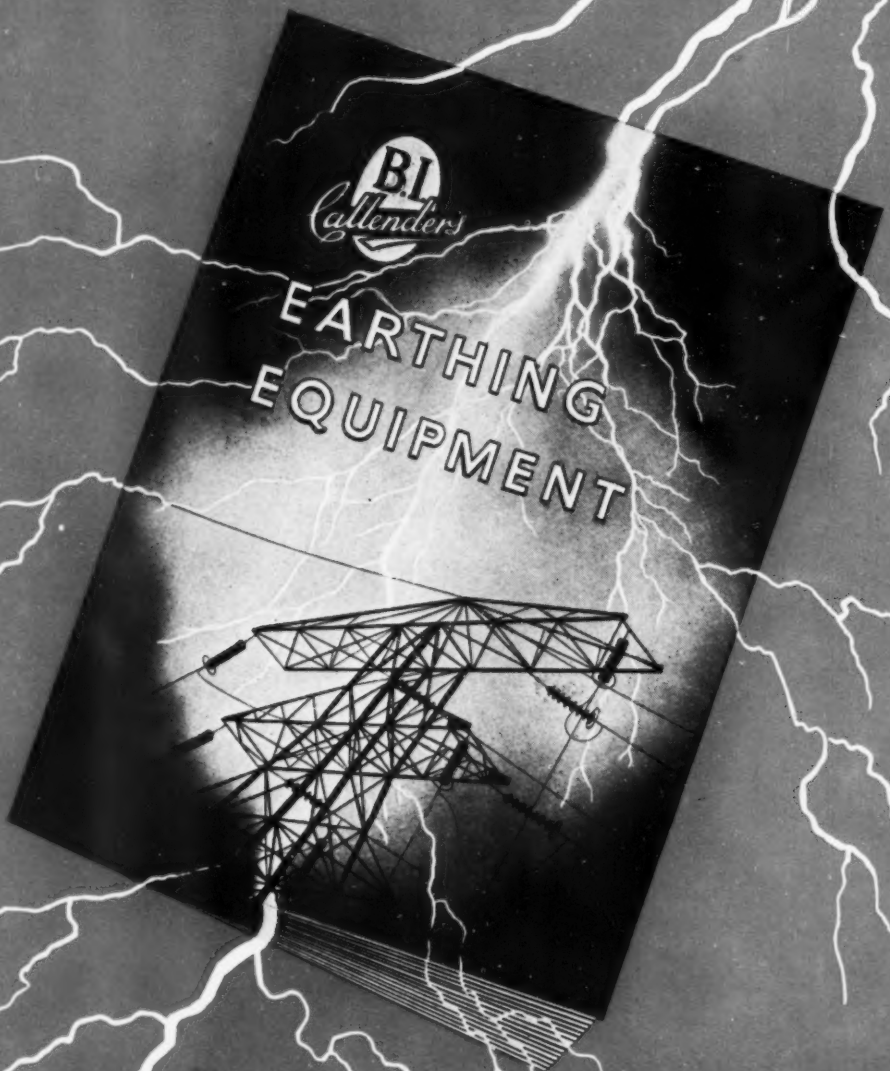
PUBLISHED BY TOTHILL PRESS LIMITED

33 Tothill Street, Westminster, London, S.W.1

Telegrams: Trazette, Parl, London. Telephone: Whitehall 9233 (12 lines).

MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466.
NEWCASTLE-ON-TYNE: 21 Mosley Street. Telephone: 22239.
GLASGOW: 87 Union Street. Telephone: Central 4646.
LEEDS: 70 Albion Street. Telephone: 27174.
BRISTOL: 8 Upper Berkeley Place, Clifton. Telephone: Bristol 21930.

Down to Earth Information



on

BICC EARTHING EQUIPMENT

This Publication (No. 335) contains more than thirty pages of technical information, tables and illustrations covering all aspects of earthing, with a description of modern methods of testing earth resistivity.

Write for your copy to-day.

BRITISH INSULATED CALLENDER'S CABLES LIMITED

21 Bloomsbury Street, London, W.C.1 · Telephone: MUSeum 1600

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Electrical Problems

ON the electrical-engineering side of hydro-electric developments, the International High Tension Conference (CIGRE) for 1954 affords an opportunity for taking stock of progress, and it is of interest to reflect on the formidable list of papers, and to note in which directions there seems to be the greatest activity.

In regard to the design and operation of hydro-electric alternators, it would seem that most of the major problems have now been solved, since there is no hint in the relative CIGRE papers of major changes in design, with one possible exception. The steadily increasing number of pumped-storage schemes, coupled with the need to operate low-head plant at more than one speed to secure maximum efficiency, has meant that attention has had to be devoted to the design of alternators to suit this method of operation. A paper from Siemens-Schuckertwerke deals with this subject. It has, of course, always been possible to achieve variable speed by means of pole commutation, but this method has not hitherto been employed with large alternators. The paper indicates that this method has now been found to be a practical proposition, a 450 kVA 50 cycle test alternator having been constructed to operate efficiently at a speed of either 333 or 273 r.p.m. as desired.

It is in the field of power transmission, however, that the scores of CIGRE papers reveal an attitude of mind that may almost be described as anxiety for the future. Ever-increasing distances have to be catered for, resulting from the needs of countries whose resources of hydro-power near to the centres of population have become fully utilised. The papers, in common with the views of experienced hydro-electric engineers we have recently encountered, indicate a still sharper focus of attention on the design and operation of long distance power-transmission lines carrying very large amounts of energy. In Japan, for example, a very-high-voltage testing station has been set up, and 275 kV lines are under construction. In America the 300 kV Ohio Valley project, the American Gas and Electric Company's 330 kV system, and the Kitimat scheme form three outstanding examples of expanding power networks, handling enormous powers which are transported over great distances. From Sweden we hear further details of operating experience on the 380 kV system and plans for its extension, including the use of series capacitors at this voltage, to improve the already large transmission capacity. Great Britain contributes for the first time operating experience on the 275 kV Grid scheme; and from Germany there comes a description of a 400 kV test station. From Italy there is news of high-voltage transmission lines being constructed to allow for even higher-voltage operation in the future.

Problems of crossing barriers hitherto regarded as insuperable, or of projects in which the natural obstacles appeared to be incapable of being surmounted economically, now appear to be on the way to solution. For example, from Canada there is an account of the two-mile overhead transmission-line span needed for the crossing over the Kootenay Lake —an engineering achievement of the highest order. The commissioning of the Gotland cable (although not the subject of a CIGRE paper this year) has marked a great step forward, since direct current, passing through the 62½-mile cable and returning through the sea, has now been proved to be practicable. Thus a sea crossing no longer presents the same difficulty of power transmission, as would be the case if alternating current alone were available.

Among the operating problems facing those who have to deal with large high-voltage power networks, that of protecting the plant from the effects of lightning is still the most serious; and since the most expensive individual item of plant is the transformer, it is natural that in the past the highest attention should have been paid to the evaluation of the stresses caused on transformers by all types of system disturbances, and the evolution of methods whereby designs may be perfected to counteract the effects of such stresses. For a number of years past many CIGRE papers have been devoted to the impulse testing of transformers, and this has been a highly

controversial issue. It may now be said that impulse testing is an established procedure, although the 1954 papers show that differences of opinion still remain as to the method of interpreting the results of impulse tests, and in the apparatus considered to be necessary for the detection of faults found during such tests. To reduce the very large cost of testing massive transformers for lengthy periods, the use of transformer models forms an innovation which may well cause a great saving, once it is established as a routine practice. In this connection it may be added that the testing of switchgear, particularly air-blast switchgear made up of a number of units in series, by the unit method, whereby a single unit is fully tested and the behaviour of the whole switch is then extrapolated from these results (once a subject of heated debate) is now an established procedure.

Thus, whereas the electrical engineer has solved most of his major problems, he is still acutely conscious of the need for power transmission over longer distances, and for the desirability of being able to bridge any natural obstacle.

British Hydromechanics Research Association

AN outstanding impression of the Open Day, held last month, at the Harlow laboratories of the British Hydromechanics Research Association was the catholicity of the work of the hydraulic engineer. Researches in progress range from work on seals and gland packings to those on vortices in pump sumps and from spillway design to the hydraulic transport of coal. Of particular interest is an investigation on the design of spillway structures for a hydro-electric scheme. An 8 in. wide transparent flume containing a model of an ogee spillway profile has been made in accordance with the Bureau of Reclamation "Datum" profile, and the performance data as given by the Bureau have been fully confirmed. On the other hand, the edge at the commencement of the ogee has been found to cause a depression that might lead to cavitation at discharges beyond about 15 per cent. above the designed capacity, but this depression disappeared after the edge had been rounded. An investigation on a bottom-sluice intake for the same scheme showed that a profile based on a circular arc gave rise to a very bad pressure distribution with a tendency to cavitation, whereas an elliptical profile gave a fully satisfactory distribution. Models of the complete spillway structure at 1 : 200 and 1 : 600 are being built.

An apparatus has also been constructed to study cavitation on hydraulic structures, in which the air pressure can be reduced to obtain true similarity with the prototypes.

A particularly interesting investigation in progress is that on the velocity distribution in centrifugal pump impellers. This is being conducted on a fan impeller having a small hot-wire anemometer attached to, and rotating with, the impeller itself, and capable of being traversed across the vane passage. The actual velocity distribution is seen to be markedly different from the uniform velocity presupposed in single-dimension theory. A test rig has also been constructed to observe flow conditions in a pump impeller, consisting of a transparent impeller and casing which will be studied in operation by high-speed photography.

In this brief note we have only been able to outline the investigations of direct hydro-electric interest. Work on the hydraulic transport of coal forms an important activity at the moment, and there are many other investigations of interest to pump manufacturers and to civil, mechanical, and chemical engineers.

St. Lawrence Seaway

THE United States House of Representatives has at last approved, by a handsome majority, the verdict of their Public Works Committee to go ahead with this great scheme and to participate with Canada in bringing it to fruition. Earlier in the year Mr. Chevrier, the Canadian Minister of Transport, expressed very forcibly the determination of the Canadian Government to proceed with the scheme alone if necessary, but left the way clear for American participation if this could be decided upon without undue delay. The incidental power which will be derived from the construction of this seaway, which will enable ocean-going vessels to have access to ports on the Great Lakes, is required by both countries but will be especially useful to the expanding industries of Canada.

Opposition to the scheme came chiefly from the eastern coastal districts, as the inland seaway will naturally divert an important section of traffic from the ocean ports there. On the other hand, industrialists in the States bordering the Great Lakes—Wisconsin, Illinois, Michigan and Ohio—have vigorously supported the scheme.

The proposed power plant construction of the international rapids would include two dams, one of which would be located at Iroquois Point, and controlling the flow of Lake Ontario, and the other at the upper end of Barnhart Island. The Iroquois dam would keep the Lake Ontario level at elevation 242 ft. and the tailwater at elevation 154 ft., developing a minimum head of 88 ft. With the available flow this should generate about 2,200,000 h.p., with an annual output of over 12 billion kilowatt hours. The cost of this part of the project based on 1950 estimate will amount to $537,000,000, of which roughly half should be carried by the U.S. Federal authorities, and the other half by the Province of Ontario.

Latest Contracts for Snowy Mountains

AN American group of civil-engineering contractors, the Kaiser-Walsh-Perini-Raymond group, has been awarded a £A20 million contract for the next stage of the Snowy Mountains project. This concern has been associated with the construction of the Boulder dam, the Grand Coulee dam, the twin tunnels at Niagara Falls, and others of the largest American schemes.

The contract is the largest ever awarded in Australia, and tenders were received from nearly every important construction group in America and many European concerns, although British contractors were not represented. The work includes one of the world's major tunnelling operations—a tunnel 14 miles long, 21 ft. in diameter and 1,800 ft. below the surface to divert the waters of the Eucumbene river under the dividing range to the Tumut river. A concrete dam 280 ft. high is also required, and a three-mile pressure tunnel at Tumut.

The English Electric Co. Ltd. have received contracts amounting to £A460,000 for the water turbines. Some Japanese tenders were received for the generators, but these are to be supplied, at a cost of £A552,000 by the Australian subsidiary of A.S.E.A.

The contract to build the associated underground power station has been awarded to a group of French firms, viz., the Compagnie Industrielle de Travaux, the Société Général d'Entreprises, the Etudes et Entreprises, l'Entreprise Industrielle, and the Société Nationale de Travaux Publics. The power house will be 300 ft. long, 60 ft. high and 80 ft. high to the crown of the arched roof. It will be situated about 1,000 ft. below surface level and will house four 80 MW vertical-type turbo-generator sets. It is understood that the French tender was £A754,000 below the Authority's own estimate for the work. Tenders were also received from firms in the United States, Australia, Germany and Scandinavia but British firms did not compete.

Norwegian Power

NEW hydro-electric generating capacity amounting to 320 MW was completed in 1953 in Norway, which is a record amount unequalled in any preceding year, and the electricity authorities in Norway hope to complete new generating capacity on the same scale as in 1953 also in each of the next four years.

Thus in the five-year period up to 1957 altogether 1,600 MW of hydro-electric generating capacity will become available. For comparison, in the 25 years up to the liberation in 1945, new capacity was introduced at the average rate of only 40 MW a year. One of the big hydro-electric development projects now being considered is the exploitation of the water power at Tokke in East Norway. Here a 400 MW power plant is envisaged which would be the largest single power plant in Norway.

A Columbia River Scheme

A DAM costing $400 million is to be built at Mica Creek on the Columbia River about 250 miles east of Vancouver, and is expected to be completed by 1961. It will form part of an extensive hydro-electric development involving the construction of nine dams in the East Kootenay area.

According to a recent statement made by Mr. Sommers, Minister of Lands, part of the power developed by this series of hydro stations will be made available to the United States, which would derive further benefit from its own chain of stations on the Columbia river by virtue of the flow control that would be exercised by the extra storage capacity provided by the Canadian dams. This additional control would increase the output of the United States stations by 30 to 40 per cent.

Unfortunately there is some conflict of interests between the two countries in the development of the stations adjoining the border, as the United States would prefer to build a station at Libby which would dam the waters of the Columbia river back into Canadian territory, and the Canadian authorities prefer to develop the power themselves rather than accept the monetary compensation which has been offered.

T.V.A. Report

CONSTITUTED in 1933, the Tennessee Valley Authority last year completed the twentieth year of its activities, and its report to Congress records the fact that in 1953 it had no less than 50 generating units under construction, if both hydro and thermal plants are considered. The Authority's plants generated 23,745 million kWh last year, hydro plants being responsible for 13,933 million and steam plants 9,812 million. Output from the hydro plants was affected by the autumn drought, being, in fact, 10 per cent less than the previous year, and this factor was combined with an increase in demand, which averaged 387 kWh per consumer. Fort Patrick Henry dam was closed during the year, making the thirtieth major control scheme on the river, and the Boone dam and power station completed, adding 75 MW capacity to the system.

Five new generating units were added to other hydro power houses during the year, and these, together with six other units in course of erection, will increase the Authority's capacity by 358 MW. At the Hiwassee dam arrangements are being made to install a pump-turbine unit. This reversible unit will be able to return water to the reservoir at the rate of 3,900 cu. ft. per sec., and will be very useful in meeting peak loads.

Rhodesian Projects

UNFORTUNATELY some difference of opinion has arisen between the Federal Government and the Government of Southern Rhodesia as to whether the Kafue or the Kariba scheme should be the first to be commissioned. The Federal Government would prefer the Kafue scheme to be developed first whereas the Southern Rhodesian Government are in favour of the Kariba scheme, on the grounds that the Kafue scheme, although cheaper, would provide Southern Rhodesia with only 100,000 MW capacity, which was scarcely sufficient on even a medium-term basis. The Kafue scheme has been estimated to cost £30 million whereas the larger Kariba scheme would involve an expenditure of £85 million.

The power anticipated from Kafue is estimated at 257 MW at 80 per cent. load factor whereas the Kariba scheme would yield 1,000 MW at 70 per cent. load factor.

Conon Valley Railway Diversion

THE railway diversion necessitated by the construction of the Loch Luichart dam and power station, to which reference was made in an article in our March issue of this year, has now been completed and the old single-platform station, opened in 1870, and about two miles of railway track have been abandoned. In addition to the laying of the new railway track at a higher level, the work involved the construction of a long stretch of stone embankment, the erection of a 100 ft. span welded steel bridge across the River Conon, a 36 ft. span bridge over the tailrace of the Glascarnoch generating station, and the building of a new railway station, a stationmaster's house and two cottages for railway workers.

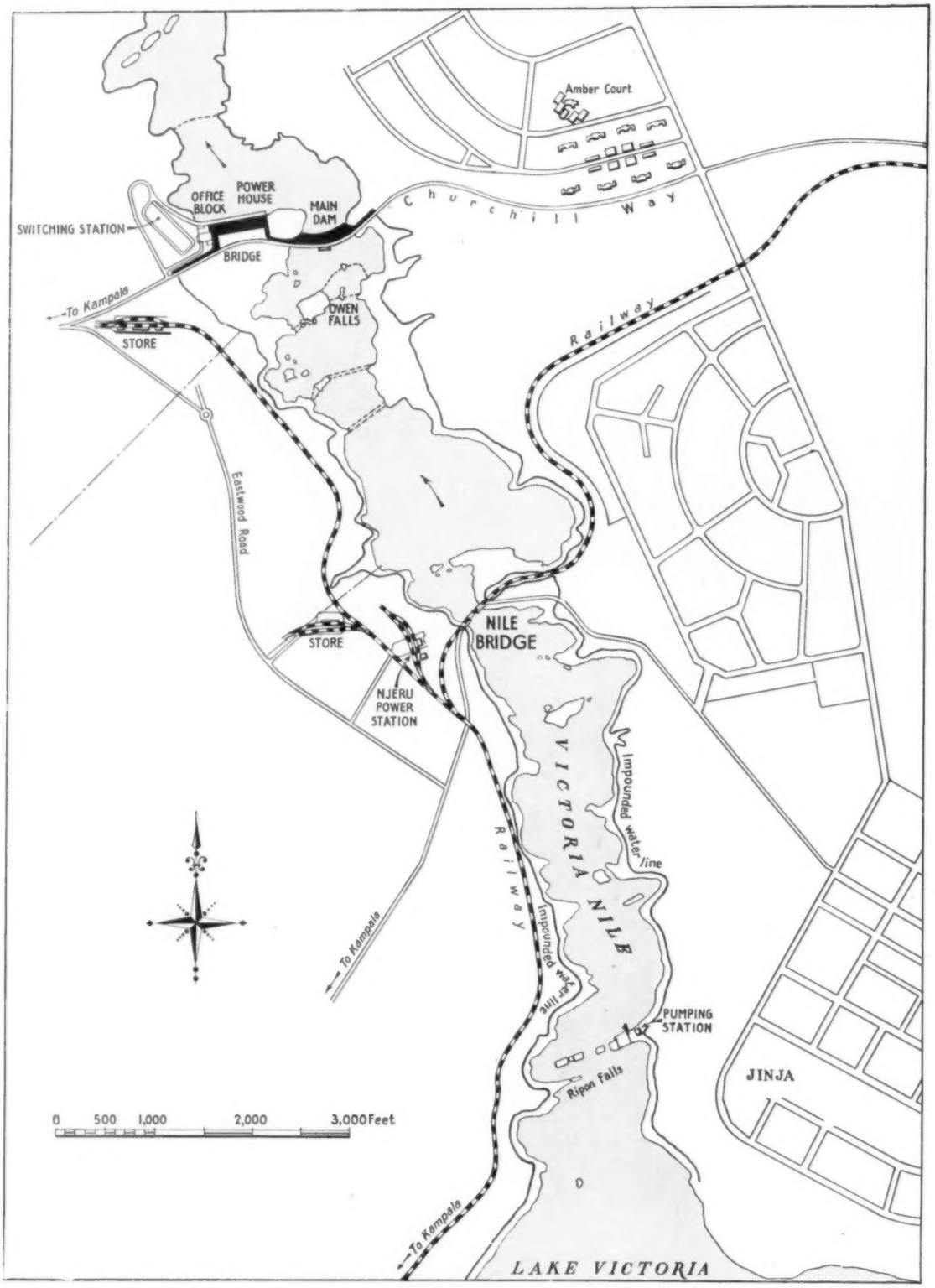


Fig. 1. General plan showing relation between Lake Victoria, Ripon Falls, Owen Falls and site of dam and power house

Fig. 2. Owen Falls dam under construction

Owen Falls

This scheme, sponsored by the Uganda Electricity Board, has a designed capacity of 150,000 kW and will harness the Victoria Nile about two miles downstream from Victoria Lake

PART ONE

UGANDA, which has an area that is roughly about twice that of England, lies entirely within the tropics and indeed is actually traversed by the equator. Its climate however is greatly modified by the fact that the entire country lies 3,600 ft. above sea level and the heat is not therefore excessive. The total population slightly exceeds 5 million, 10 thousand of whom are Europeans, 37 thousand Indians and the remainder natives. Agriculture is the chief industry and the main exports are coffee and cotton.

To secure a better standard of living and a more balanced internal economy, industrial power is necessary; in Uganda there are no known indigenous deposits of either coal or oil, and the distance from the nearest port, some 700 miles, puts a premium on imported fuel. Fortunately there are substantial hydro-electric resources as the main branch of the Nile traverses the entire country, falling some 1,700 ft. between Lake Victoria and Lake Albert which lies about 250 miles to the north-east. The river leaves Lake Victoria at its northern extremity and shortly after emerging from the lake it cascades over the Ripon Falls and then, about 1½ miles downstream, encounters the Owen Falls, immediately below which the new dam and power station are situated. From the lake to the site of the power station the river has a natural fall of 70 ft., the channel being worn through a hard amphibolite rock which makes an excellent aggregate for the large quantities of concrete used in the scheme. At the site chosen for the dam, the channel was originally narrowed down to 500 ft. by a spur of rock which projected from the east bank. At the Ripon Falls the river is some 900 ft. wide and the flow is divided into several separate channels by a number of small islands. About half the water flowed through the most westerly of these channels and advantage was taken of this fact to effect a temporary control of

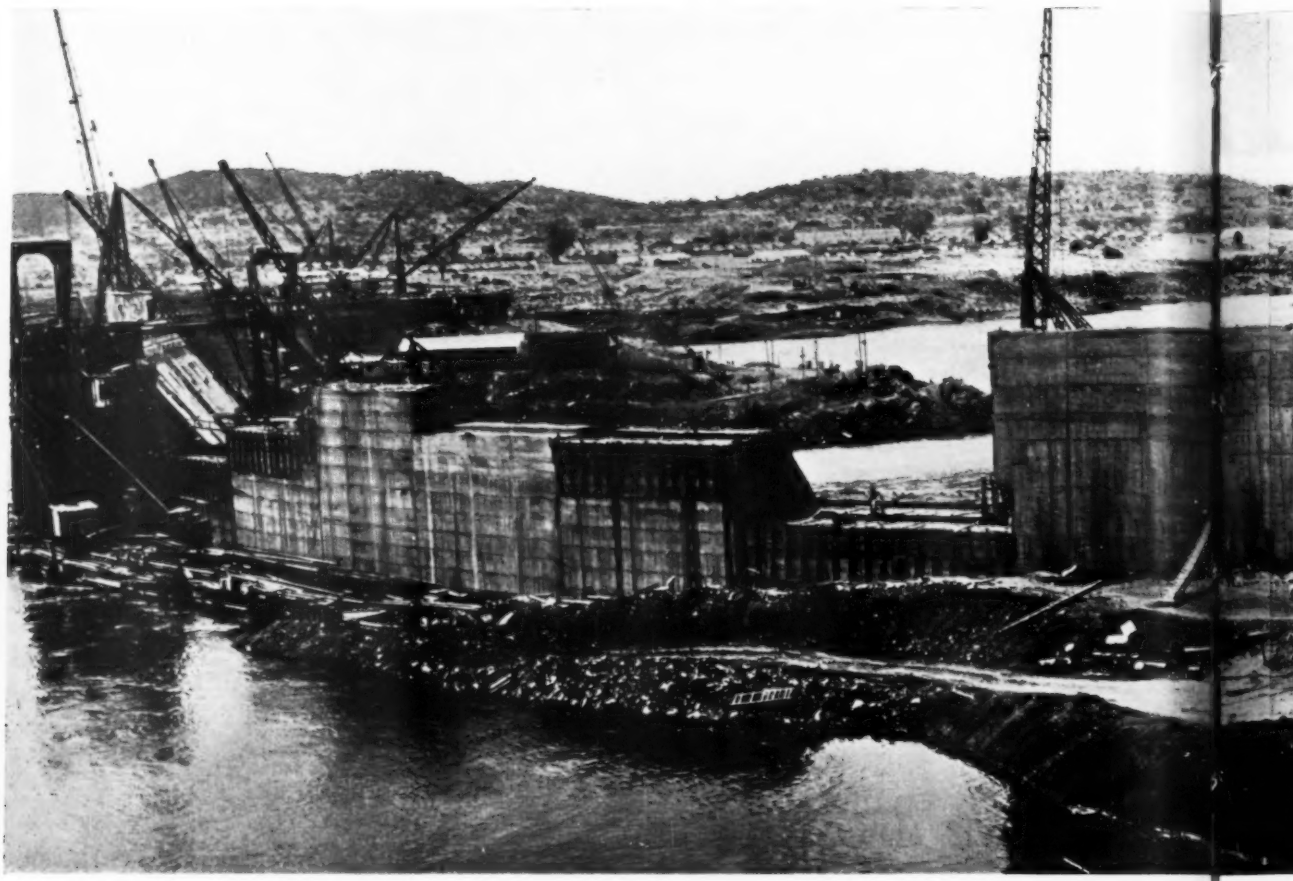


Fig. 3. Panorama of east end of main dam from upstream

the river during the constructional operations at the dam and power station. To effect this, a sluiceway was erected, within a cofferdam, on a low promontory from the east bank, and the western channel blocked by a rock-filled crib which was erected as a tower on the east bank and then felled into the channel by an explosive charge. The framework of this tower consisted of local timber reinforced with steel wire-rope netting and was built in stages and filled with rock as the height increased. With the crib in position it was possible to build up a temporary dam by means of which the flow could be partially controlled by inserting or removing stop logs as required, in the sluiceway. By means of these simple measures the flow has been successfully regulated to the established average of 21,500 cusecs (600 cu. m. per sec.). Actually the size of Lake Victoria in itself affords a safeguard against sudden and excessive flooding, as an increase of a few inches in the level represents an enormous amount of water. The lake surface has a natural elevation of 3,716 ft. O.D. and once the dam is completed the maximum water level will be raised to 3,723·5 ft. At the time of writing, however, the top of the dam has not been fully completed and the turbines are working at an intermediate level ranging about 3,697 ft. With the

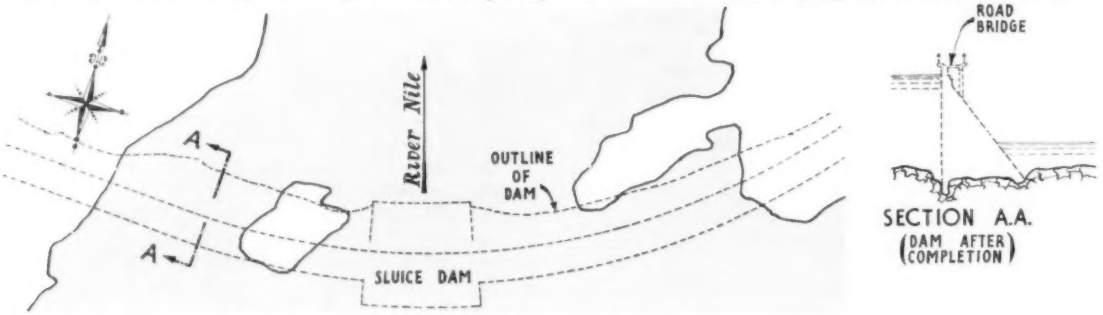
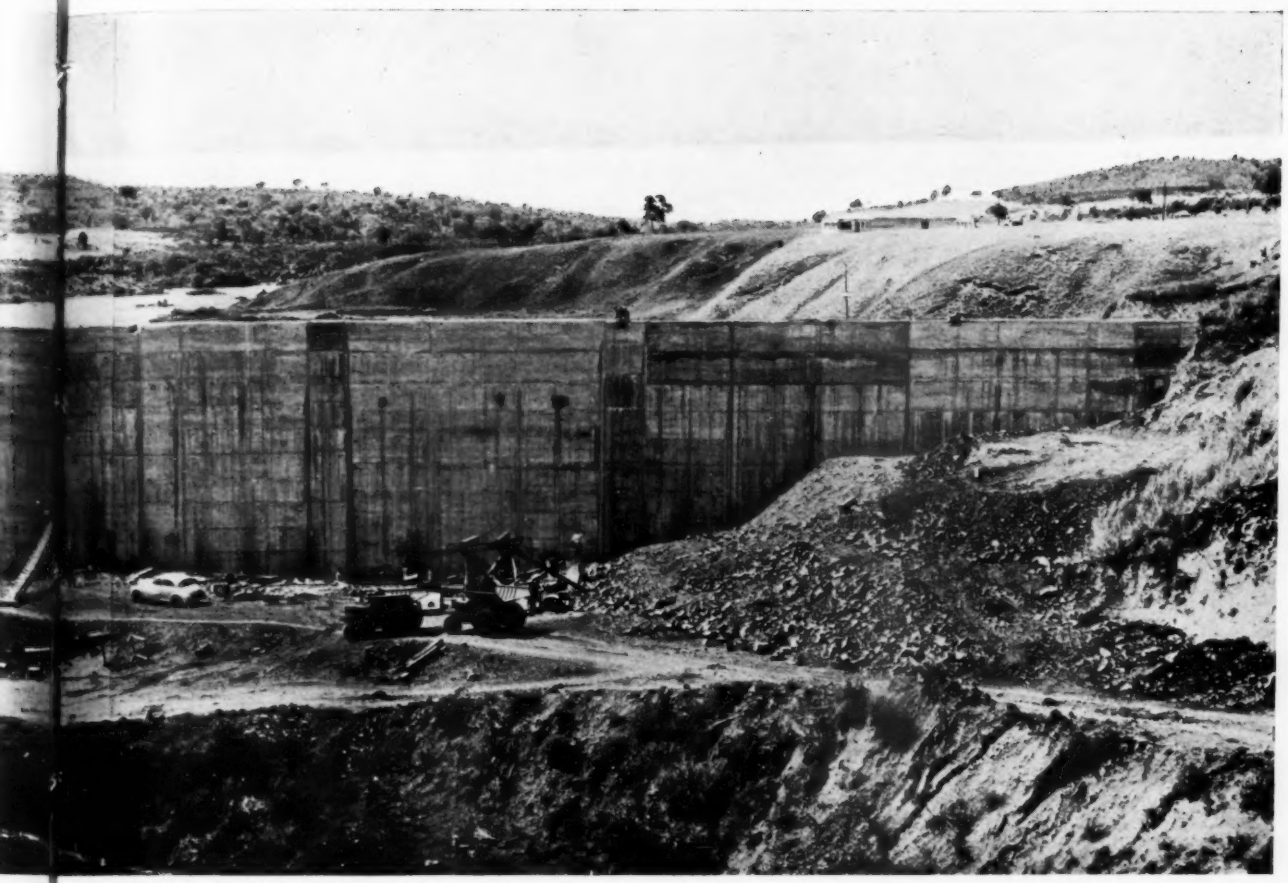


Fig. 4. Site plan showing dam in outline and cross section



maximum water level the storage capacity will be 166 million acre ft. A curious feature of the catchment basin is that the storage area represents a most unusual proportion of the total drainage system. The catchment has an area of 103 thousand square miles and of this the lake occupies almost exactly 25 per cent., having an area of 26 thousand square miles. Unfortunately a water surface of this great size, especially in the tropics, gives rise to heavy evaporation losses and is not, consequently, without its disadvantages. On the other hand, the flow is peculiarly regular and does not range above a variation of about 4·5 : 1. Flow data are available for over fifty years back and show the mean discharge to be 22,000 cusecs, the maximum recorded being 45,000 and the minimum 10,000.

The main features of the scheme comprise the main dam in which six sluices are incorported to control the flow of the river; an intake dam, upstream of the power house and incorporating the

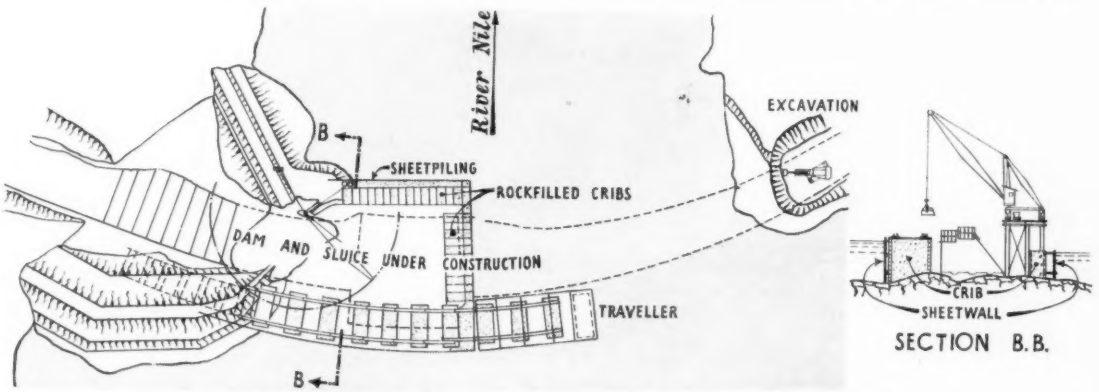


Fig. 5. Method of constructing second part of western half of dam

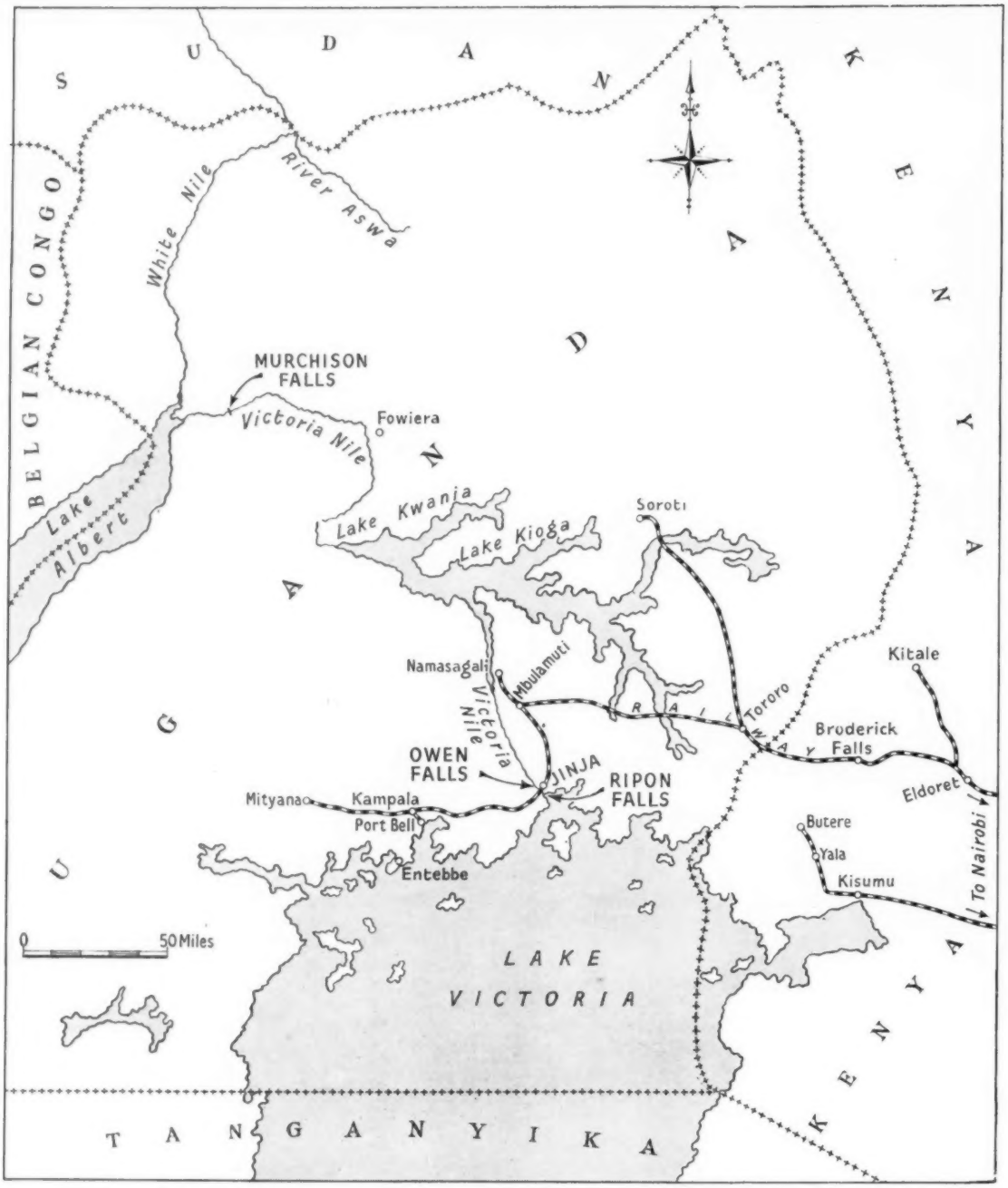


Fig. 6. Map of area in which Owen Falls scheme has been carried out

trash racks; the power house block; a road bridge which crosses over the headrace and the main dam; and a switching station, together with various ancillary works. The main dam is of the gravity type, curved in plan, and has a maximum height of 100 ft. above cut-off level. When completed the power station will have a capacity of 150,000 kW made up of ten sets of 15,000 kW each. Two of these sets are now working and a further four are in process of erection, but the remainder will not be installed until there is a sufficient demand for energy. It will be possible, however, to install these four remaining sets with a minimum of further site work as every provision will be made for them before the contractors leave the site.

The consulting engineers for the civil work are Sir Alexander Gibb & Partners, while Messrs. Kennedy & Donkin were responsible for the design and planning of the mechanical and electrical engineering sections. It was on the joint report (July 1948) of these two consulting firms that the decision was

Fig. 7. Aerial view of the site showing the succession of falls

Fig. 8. Ripon Falls barrier, base of tower blasted and tower falling

Fig. 9. Ripon Falls barrier, west bank, after felling tower

made to go ahead with the scheme. The contract for the civil-engineering work and incidental building was placed with The Owen Falls Construction Company in October 1949; this concern being a partnership* of four British and four Dutch firms who co-operated very successfully in rebuilding the devastated port of Rotterdam.

A first task was the design and placing of the cofferdams. Model tests were carried out by the contractors in the hydraulics laboratory of the Imperial College of Science & Technology, South Kensington, in which data were accumulated about the hydraulics of the project at various stages of construction. It was these tests, incidentally, that led to the decision to control the flow at Ripon Falls. The power station is sited on a rocky spur projecting from the west bank, the contours of which enabled the construction to proceed with a cofferdam on the downstream side only. At the centre this spur forms a saddle which, with slight enlargement, is

*Christiani and Nielsen Limited; Dorman Long and Co. Ltd.; J. L. Kier and Co. (London) Ltd.; Edmund Nuttall, Sons and Co. (London) Ltd.; Hollandsche Beton Maatschappij N.V.; Naamlooze Vennootschap Internationale Gewapendbeten Bouw; N.W. Nederlandsche Anneming Mij.; N.V. Nederlandsche Beton Maatschappij Bato.

able to carry the full flow of water required by the turbines.

The type of cofferdam adopted consisted of lines of interlocking sheet piling supported by heavy steel joists bearing against rock-filled timber cribs. These cribs, which measured 40 ft. by 16 ft. in plan and were built to a maximum depth of 50 ft., were made from locally grown eucalyptus poles, 10 in. in diameter, the lower portions being wrapped around with steel torpedo netting to prevent the rock from running out. They were dropped into position by means of a structural-steel travelling gantry, mounted on wheels, which had a cantilevered end that projected over the water, while the main beam rested first on the river bank and subsequently on the cribs which had already been placed. This structure, or "traveller" as it was called, weighed some 250 tons and was moved by winches. Each crib weighed about 40 tons and the lowermost section was carefully constructed to fit the contour of the bed rock on which it was placed. To determine the contour, a series of soundings, arranged on a definite pattern, were made with a length of rail suspended from a 10-ton derrick. From these soundings it was possible to reconstruct the contouring of the bed and tailor-make the bottom of the crib to an exact fit. Once lowered accurately into position the crib was filled with broken rock. All this piling was of the heaviest K3 type supplied by Dorman Long & Co. Ltd. Lowering the cribs proved to be a rather tricky job on occasions as the current was flowing at about nine knots, entailing a horizontal load of 20 tons. Furthermore, once the crib was in position it had to be

Fig. 10. Cofferdam, looking upstream, showing cribs Nos. 10-13 and two pump installations

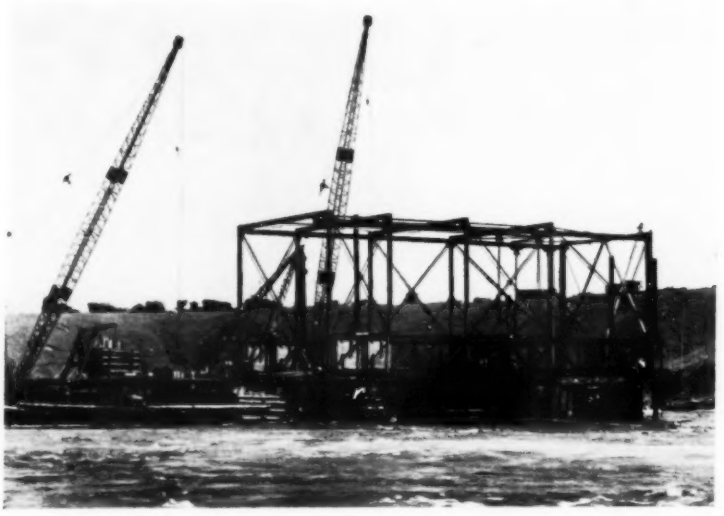


Fig. 11. Structural steel traveller on main cofferdam, showing sheet piling and crib No. 8 in position

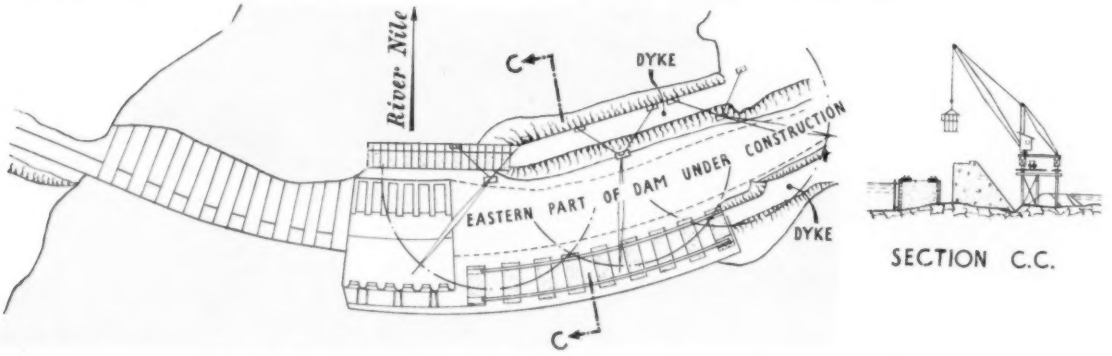


Fig. 12. Arrangement of cofferdams for completion of eastern portion

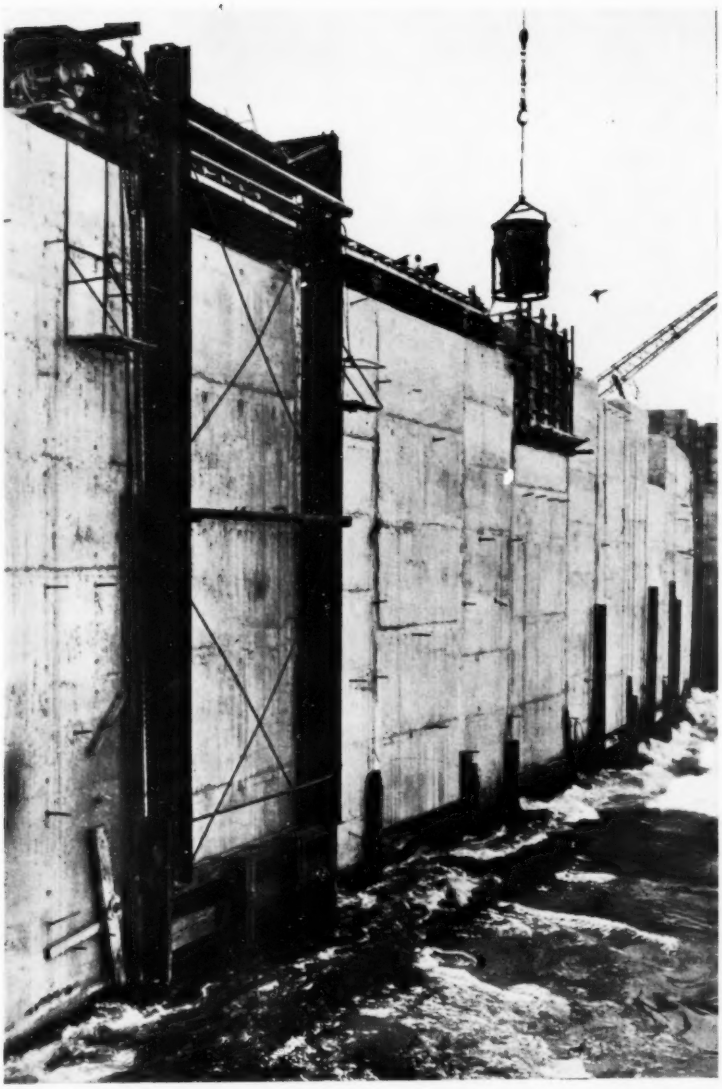


Fig. 13. Closing gate and extension over temporary opening No. 1

held steady until sufficient rock had been loaded to make it stable. The distance between adjacent cribs is 16 ft. and this interval had to be bridged over before the traveller could be moved forward to lower the next crib. Once a routine had been formed, however, the placing of the cribs went forward smoothly and without hitch.

The sheet piles and supporting joists were placed by means of derricks mounted on specially placed cribs of their own. Some difficulty was experienced in sealing the lower end of the piling in certain sections where the ground rock proved to be fissured or contained pockets of gravel. In one case the gravel attained a depth of 25 ft. Sealing was ultimately effected by lowering bags of clay and concrete, which were carefully placed in position by divers, and this treatment was followed up by a clay blanket 6 ft. thick and 20 ft. wide. This again had to be protected by a further line of sheet piles to prevent it from being swept away by the current. The whole was then thoroughly grouted after which the water was pumped out in 24 hours without further difficulty. The dam, which is of the gravity type, was normally built of 45 ft. wide blocks with 5 ft. shrinkage gaps, but in the portion including the temporary openings the blocks were 15 ft. wide with 15 ft. gaps. The shuttering consisted of 16 ft. by 5 ft. 6 in. panels, giving a 5 ft. lift. Precast elements were used for the switching station, road bridge, for facing and for the wall panels of the power station.

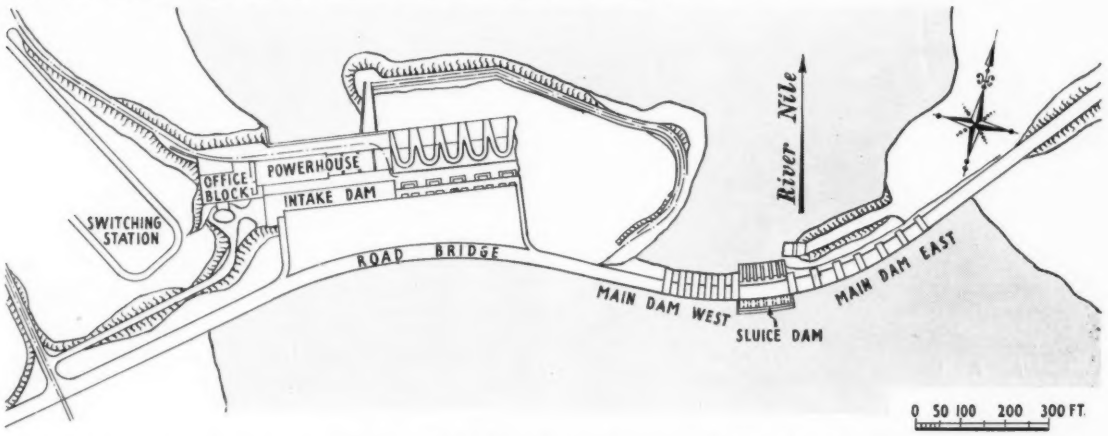


Fig. 14. Stage of construction reached at time of commissioning the first turbine

All drilling for the grouting work was accomplished by C.P. diamond drills from holes normally placed at 5 ft. centres and carried down to a depth of 50 ft. The cofferdams were constructed in three stages in order to provide ample space for the river flow. A first operation was the erection of two combined rock earth dykes to enclose the channel between the west bank and the island (Fig. 5). While this work was proceeding the peninsula projecting from the east bank was removed to compensate the loss of flow incidental to blocking off the western portion of the river. Temporary openings were left in western portion of the main dam, and the remainder of the western half, incorporating the permanent sluiceways, was protected by further cofferdams as shown in Fig. 5. The sluice dam cofferdam was so arranged that it could be linked with either the east or west cofferdams, to enable work to proceed over the largest possible period on this complicated section. The eastern half of the dam was completed under the protection of a crib and sheet-piling cofferdam on the upstream side, and a combination of earth dykes and cofferdam on the downstream side (Fig. 12).

The sluices are designed to pass the maximum recorded flow of the river and have a capacity somewhat in excess of 45,000 cusecs.

Details of the aggregate reduction and handling plant, which was supplied by Pegson Limited, of Colville, were given in our February 1952 issue and to this article interested readers are referred*. For the most part the excavated rock serves as the aggregate but is supplemented by additional rock obtained from an adjacent quarry. Fines from the aggregate production were used to supplement the sand, which was obtained from the lake shore at Kabugoga and brought to Jinja, a distance of some 15 miles, by lake barges, whence it was transported three miles to site by lorries. The sand is washed by pumping and then dewatered in a Mosley sand cone. It is then batch weighed in Winget equipment and fed to the mixers with the aggregate, which has also been batch weighed to meet the concrete specification. Initially the cement was entirely supplied from Europe, mainly from Great Britain, but recently has been substantially supplied from a new works at Tororo. At first it was supplied in bags but to cut down the expense arrangements were subsequently made for it to be delivered in bulk containers. Table I shows the various classes of concrete used.

* "Aggregate Production at Owen Falls," WATER POWER, February 1952, pages 71-73.

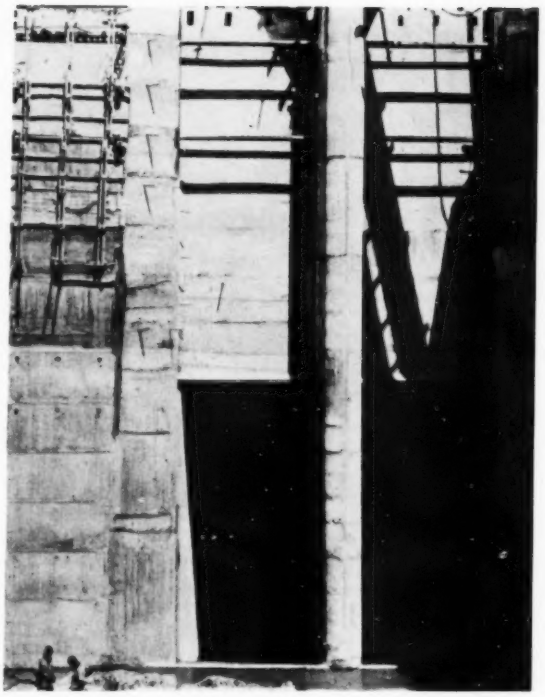


Fig. 15. Intakes Nos. 9 and 10 looking north

Fig. 16. Power-house foundations showing steel reinforcement

Fig. 17. Nos. 1 and 2 bell-mouth openings in sluice dam

Fig. 18. Precast slabs and in situ beam shuttering in main dam

Fig. 19. General view of main dam showing progress August 16, 1953

TABLE I—VARIOUS CLASSES OF CONCRETE USED

Class of concrete	Approx. proportion	Ordinary Portland cement	Nominal sand	Coarse aggregate	Min. compressive stress at seven days
		cwt.	cu. ft.	cu. ft.	lb. per sq. in.
3/3	1 3¼ 5	3	10	20	1,500
4/3	1 2 4	4	10	20	2,000
5/3	1 1½ 3	5	10	20	2,300
5/1½ } 5/¾ }	1 2 3½	5	12	20	2,300
6/1½ } 6/¾ }	1 1½ 2¾	6	12	20	2,500
8/1½ } 8/¾ }	1 1¼ 2	8	12	20	3,000

The concrete is handled by ten Butters derricks, mostly of 10-ton capacity, in Blaw-Knox skips of 2 cu. yard capacity. From the batching plant the skips are handled by Ruston & Hornsby diesel locomotives. Four Bucyrus-Erie type 38B excavators were in service for mucking out the foundations and general duties on site.

The civil-engineering work is estimated to cost about £6 million. The total excavation, mostly of

(Continued on page 231)

Book Reviews

Kempe's Engineer's Year Book, 1954. Morgan Brothers (Publishers) Limited, 28 Essex Street, Strand, London, W.C.2. Two volumes in case. 3,000 pp. Price 75s. net. Postage in Great Britain, 2s. 6d.

This famous yearbook has long been a veritable *vade mecum* for the engineer of whatever persuasion, but the 1954 edition has been completely rewritten, set in a clearer type, and supplied with about 1,500 new illustrations. Eight new chapters have been added —on Atomic Power, Explosives, Electrical Engineering Fundamentals, Industrial Safety, Mechanical Handling, Plastics, Powder Metallurgy, and Theory of Structures, making a grand total of 79 chapters. In addition, every chapter in the book except that on Gearing has been drastically revised, and some of the chapter classifications have been rearranged. The index has been enlarged to 17,000 references.

The chapter on Water Turbines, which runs to some 30 pages, has been contributed by M. Braikevitch and G. F. W. Adler. A chapter on Water Engineering, by R. C. S. Walters and P. B. Mitchell, of nearly 80 pages, covers both water supply and water power, including hydrology, dam construction, types of hydro-electric schemes, and so forth, and there are numerous other chapters containing information relevant to hydro-electric practice.

"Hydraulique et Electricité Françaises" (French Hydraulics and Electricity), a special publication of "La Houille Blanche," rue Paul Verlaine, Grenoble, France, 8½ in. by 11½ in., 413 pp., 395 ff. Price in France, either French edition with Spanish summaries or English edition with French summaries, paper covers, Fr. 2,000·00, cloth bound Fr. 3,000·00.

The first and most important part of this publication, devoted to hydro-electric development proper, fills no less than almost a half of the book. It is divided into six geographical sections, the first four dealing each with one of the main regions from which France draws her water-power supplies (Alps, Massif Central, Pyrénées, and Rhone), and the two following sections with Algeria and Morocco respectively. In each of these six sections detailed maps show the main developments, either completed, in progress, or still at the project stage; major developments, such as those of the Isère, Dordogne and their tributaries, are the subject of separate chapters. The survey of the well-known Rhone developments extends to 50 pages. The article on Hydraulic Research, contributed by M. P. Danel, Director of the "Laboratoire Dauphinois d'Hydraulique," is of special interest, dealing as it does with models and their applications. A chapter by the same author on irrigation follows; the synoptic table of agricultural hydraulic research could be easily applied, with appropriate modifications, to hydro-electric research.

The contribution of thermal plants to French power generation is reviewed at length, special stress being laid on the great power plants attached to coal mines; this is followed by a survey of the French system of energy transmission and inter-connection.

In the section "Studies," no less an authority than M. A. Coyne discusses the part to be played by consulting engineers and designers in dam construction. Other articles in this section deal with "Geophysical prospecting by electrical methods in civil engineering practice," "Modern surveying methods for hydraulic projects," and "Soil investigation and hydraulic structures." The work concludes with chapters on the achievements of French contractors in hydro-electric development, and the contribution of French manufacturing engineers; in this latter chapter, we should like to draw attention to the article on steel-penstock technique.

Actions Eoliennes. Phenomenes d'Evaporation et d'Hydrologie Superficielle dans les Regions Avides. Service des Puolications, Centre National de la Recherche Scientifique, 45 Rue d'Ulm, Paris V. Price 2,500 fr.

With the publication of this volume we now have available the complete proceedings of the International Conference held at Algiers in 1951 on the problems of desert regions. Twenty-six papers were presented, and they are grouped under three heads: Wind Phenomena (particularly the action of wind on sand), Miscellaneous Questions relating to Sand Dunes and Soils, and Evaporation and Surface Hydrology. The volume includes summaries of the discussions, and is, of course, in French except that an English summary of each paper is given.

Specification for Capacitors for Power Systems: First Edition, Part I. International Electrotechnical Commission Publication No. 70-1. 39, Route de Malagnou, Geneva. Price, 3 Swiss francs plus postage.

This specification contains safety rules and quality regulations and tests for capacitors for connection to a.c. low and high-voltage systems with a frequency up to 100 Hz for use for power-factor correction, for coupling with other electric systems, for over-voltage protection and other low-frequency a.c. applications. The specification applies to both capacitor units and assemblies of capacitor units with accessories to form complete capacitor equipments.

A second part of this specification dealing with installation and operation is in course of preparation. Ultimately, it is intended to issue both parts in one publication.

Etude et Tracé des Ecoulements Permanents en Canaux et Riviéres. (Analysis and Plotting of Permanent Flow in Canals and Rivers). By R. Silber. Dunod, 92, Rue Bonaparte, Paris VI. 1954. 194 pp. 180 ff. 1 chart. Paper covers. Price, 1,800 fr.

Even in the simplest of cases the study of flow at a free surface is arduous because of the existence of quantities that cannot be evaluated analytically, and classical methods of approach are either long and laborious or simplification is sought by the introduction of empirical functions. In this book the author presents what is believed to be an original method of approach, for he develops what he terms a "universal equation" which is competely amenable to analytical treatment, and depends on dimensionless variables. This equation enables a "universal diagram" to be plotted, in which the net depth is given as a function of net discharge and related to net energy.

This diagram is applicable both to natural watercourses and to canals, and is claimed to provide both qualitative and quantitative treatment without involving either the labour of classical methods of calculation or the use of empirical assumptions.

Criticism of Elutriation Systems for the Treatment of Sand for Concrete

The intensive development in concrete technology which began after the end of the second world war brought to the fore the importance of classifying fine sands. What is called "air entrainment" on the one hand, and the mastering of the screen analysis curves for fine sands on the other, are among the few innovations for which decisive successes can be registered in the technology of concrete.

By DR. TH. EDER, Vienna

IT has been proved by investigation and practical experience that the quality of concrete is markedly influenced by the composition of the fine classes in the inerts. All reactions between the cement and the inerts depend upon the surfaces, which are in direct relation to the particle sizes. Thus, by reducing the radius of a spherical grain to half, the specific surface is doubled.

The composition of the small sizes of the inerts is an essential factor in determining conditions, as also are the cement content, the water-cement ratio, the workability and the frost resistance of concrete. In large construction jobs the classification by screens is rarely carried out for smaller sizes than 3 mm., but it is just the composition of the minus 3 mm. class that has so decisive an effect on the strength and frost resistance of concrete and also on the other conditions cited above.

A few years ago engineers in the United States began to treat the smallest sizes (minus 4 mesh) by the "hindered settling" method. As the precision of separation by such an elutriation system does not permit a very exact classification, the only thing that could be done was to reject one or other of the products obtained from the six or eight outlets of the cone-shaped elutriation units, in order to obtain a correction of the screen analysis curve. The whole of the zero to 4·7 mm. material was stored and conveyed as a whole to the concrete plant. This created some difficulties; for instance, the segregation which took place in the stockpile frequently annulled the effect of the previous classification, and the difficulty of regulating the elutriation units according to the screen analysis involved a delay of from one to two hours; but apart from these drawbacks certain progress was made.[1, 2, 3]

In the summer of 1952, for the construction of the Mooser dam near Kaprun, Austria, the first vertical elutriation plant for the exact separation of the fine sands at 1 mm. was put into operation. This new elutriation plant was capable of effecting an exact separation, equivalent to wet fine screening. The classification at 1 mm. size had already been projected for the construction of the Limberg dam, near Kaprun, but could not be carried out for lack of appropriate equipment.[4, 5] At Kaprun the "Rheax" system was used and this also gave a successful performance in the summer of 1953 in the construction of the Danube dam at Jochenstein. It has now been decided to use the same vertical elutriation system for the erection of three great dams in Switzerland.

The quality of concrete is further affected to an extraordinary degree by the dust content of the aggregates. Here we wish to cite an important investigation by A. Wogrin,[6] who demonstrated that the absence of dust particles below 60 microns is essential not only for frost resistance but also for the efficient application of air-entraining agents. The results of this investigation have induced the Tauernkraftwerke to maintain generally the particles below 60 microns to not more than 1 per cent. in the zero to 1 mm. material. Elimination of dust below 60 microns and of mica below 0·3 mm. is possible only by elutriation.

Not every elutriation system is suitable for this purpose and the author well remembers a construction job in Europe some years ago where it was conceived that the dedusting of sand could be effected by a spiral classifier with a regulated flow of water. The resulting concrete did not, however, reach the minimum strength required, partly due to the extraordinary content of residual dust.

Now, what are the requirements of an elutriation system?

Precision of Separation. If the material passing through a 3 mm. screen does not contain any grain over 3 mm. and the residue no grain below 3 mm., we have a case of ideally precise separation; this, of course, will never be possible, not even by dry screening with standardised laboratory screens. In this matter it seems appropriate to use the oversize content of the fine class and the undersize content of the coarse class, to express the precision of the separation. However, the oversize and undersize contents do not only depend upon the precision of separation of a classifier, but also—and essentially—upon the size composition of the raw material.

This will be evident when considering the performance of a very irregularly constructed screen of 3 mm. with wet material and heavy overload (both representing conditions for low separating efficiency) and fed with pieces 1 mm. and 10 mm. size. The material passing the screen will not contain any size over 3 mm. and the residue on the screen will be free from any size below 3 mm. On the other hand, if we test the performance of a standard 3 mm. screen with a discrete feed of dry 2·5—3·5 mm. size grains, we shall doubtless find large percentages of oversize and undersize grains.

Fig. 1. Pioneer fine-sand treatment plant at Kaprun, installed through the initiation of H. Böhmer and A. Wogrin and in service since the summer of 1952

For a certain construction job it was decided, as a condition for the 3 mm. vibratory screening, that the material passing through the screen should not contain more than 2 per cent. of over 4 mm. size, while the coarse material should not contain more than 2 per cent. of below 2 mm. size. This definition of precision of separation is an improvement in that it fixes a certain limit zone for over- and under-size particles.

In the present case, in order to raise the throughput of the vibratory screens, it had been necessary to insert a screen with rectangular meshes of 3×7 mm. The fines so obtained showed nearly 10 per cent. grains over 4 mm., and the coarse materials were free from undersize grain below 2 mm. The grain parting diameter had been displaced to 3·5 mm., which means that the performance of the screen with rectangular meshes was equivalent to a square mesh screen of 3·5 mm. Thus the guaranteed conditions for oversize and undersize were not met, in spite of a generally satisfactory precision of separation. There is no doubt that it might have been possible to fulfil the conditions by inserting a rectangular mesh screen with $2{\cdot}5 \times 5$ mm. meshes; however, the manufacturers and their customers preferred to arrange the matter by changing the terms rather than the meshes.

Exact Definition and Measure of the Precision of Separation. In coal-washing plants the precision of separation of a system operating according to density (concentrating tables, etc.) is evaluated by the Tromp distribution curve. Tromp's distribution curve has also been introduced successfully for screening and elutriation operations, and enables the precision of a separation system to be determined without reference to the composition of the raw material. In the following an example will be given of calculating a Tromp distribution curve.

An elutriation process may so separate, for instance, 100 lb. of raw material that 40 lb. will pass to the fine and 60 lb. to the coarse class. The fines may further contain, for instance, 20 per cent. of 0·3—0·5 mm. material, while the coarse may not contain more than 3 per cent., so that it can be affirmed that 8 lb. of the 0·4 mm. particles (the average size of 0·3—0·5 mm. class) will pass to the fines and 2 lb. to the coarse. The probability of the 0·4 mm. particles to pass to the fines will accordingly be 80 per cent. Every size has a different probability to pass to the fines. If in a co-ordinate system the sizes are plotted on the horizontal axis and the respective probabilities on the vertical, we shall obtain the Tromp distribution curve. The more steeply inclined the curve, the better will be the precision of separation. The size from which 50 per cent. will be found in the fines and 50 per cent. in the coarse is the grain parting diameter K_{50}.

The relation of the sizes, 25 per cent. of which pass to the fines (K_{25}), to the other size from which 75 per cent. will pass to the fines (K_{75}), is called dispersion of diameters $\kappa_{25/75} = \dfrac{K_{25}}{K_{75}}$

The more exact the system of separation, the lower will be the grain dispersion. This factor should be 1 in the case of ideal precision, but it is evident that this will never be accomplished, and specially not by

hydraulic elutriation, because in practice the grains are never spherical, a fact that would lead to differences in the screen analysis even in the case of an ideal classification.

A good vertical elutriation system may be required to effect a dispersion of 2 for the parting diameter 1 mm. Certain elutriation equipment enables grain dispersions of 1·4 to be obtained. A good horizontal elutriation system may reach a dispersion 3, while it may be possible by combined classification to obtain dispersions 1.7. 700.

Evaluation of the precision of separation will soon lose the appearance of mathematical complication for anyone who has tried to understand the Tromp curve. Every laboratory technician, familiar with multiplication and division by calculus, will be able to calculate the precision of separation in 15 minutes at the most. On the other hand, it should be emphasised that to guarantee a classification process by the oversize and undersize contents only, as is often required, lacks sense in the same way that it is impossible to guarantee the average speed of a sailing boat to be, say, 8 m.p.h., as the speed does not depend on the boat only but also on the wind.

The oversize and undersize contents depend not only on the equipment but also on the raw material.

Advantages of a High Precision of Separation at 1 mm.

1. *Low Losses of Sand.* In order to obtain an optimal screen analysis curve, a raw sand of any composition is classified into different sizes which are proportioned and mixed. Construction companies depending on their own sands are able to modify the screen curves by rejecting the one class or another. The greater the precision of separation, the lower will be the quantity rejected in order to obtain a required change in the screen curve. This will be evident when considering an example in which an unprecise separation divides the material into two classes of the same composition as the original product. In this case there may be rejected an infinite quantity of the one or the other class without any effect on the size composition of the mixture. The following is an industrial example. The 0—3 mm. class of a natural sand may have the composition:—

0—1 mm. 30 per cent.
1—3 mm. 70 per cent.

The following two classes are obtained by exact vertical hydraulic elutriation (κ about 2):—

0—1 mm. 25 per cent. containing 10 per cent. grains over 1 mm.
1—3 mm. 75 per cent. containing 10 per cent. grains below 1 mm.

The following classes were intermediately obtained by a low precision elutriation (κ above 10):—

0—1 mm. 8 per cent. containing 15 per cent. grains over 1 mm.
1—3 mm. 92 per cent. containing 25 per cent. grains below 1 mm.

If the 0—3 mm. class is required to present the composition:—

0—1 mm. 45 per cent.
1—3 mm. 55 per cent.

it is easy to calculate the desired composition for the first case ($\kappa = 2$), i.e. 25 lb. of the fine class must be mixed with 32 lb. of the coarse class, both obtained from 100 lb. sand 0—3 mm., with a reject of 43 lb. of coarse material. The useful yield is 57 per cent.

With a separation of low precision ($\kappa > 10$), 8 lb. of fine sand must be mixed with 16 lb. of coarse sand, both obtained from 100 lb. of raw sand thus leaving 76 lb. to be rejected. The yield of sand is here only 24 per cent. The yields are not always so obviously affected by the precision of separation but it always has a certain importance. The greater the precision of separation, the lower will be the losses by reject.

2. *Constancy of the Screen Curves.* In classification equipment having a low precision of separation, the composition of the different classes will depend to a considerable extent on fluctuations in the raw materials. But it is not only the precision of separation of a classification system which is responsible for size fluctuations in the classified material. High precision in a system is useless when it is impossible to maintain constancy in the conditions of the classification; for instance, in many primitive elutriation plants it may be possible for a workman to alter the conditions by opening or closing the water inlet, or for the water flow to depend on the drainage from the vibratory screens, which may be variable. Further, it has often been shown that the performance of some plants is difficult to check and this may cause a great deal of trouble before defective operation is discovered.

If a natural sand, for instance, presents a uniform screen curve that is only slightly different from the optimum limit of that required (a case not very frequent but sometimes possible), the separation of the fines obtained from the last screening by a low-precision process might affect the quality of the final product so very adversely that better results would have been obtained by not classifying it at all. Low precision processes require very frequent checking of the classified products by screen analysis and continues calculation of the proportions, according to analysis figures, in order to maintain the size composition of the inerts constant. As an anlysis usually requires one or two hours before the results can be evaluated, it is impossible to check the conditions existing at any one moment. On the other hand, experience has shown that the vertical elutriation equipment is not only able to operate with a high precision of separation but also

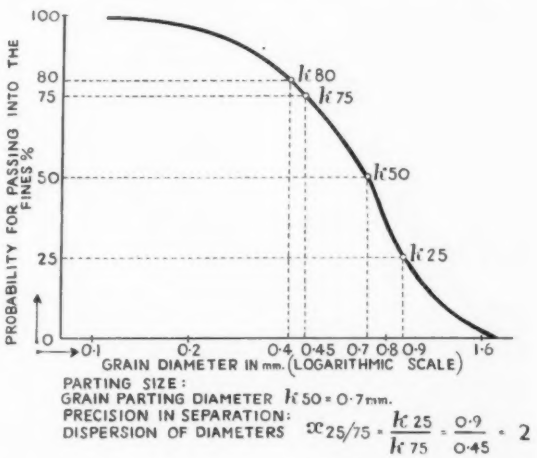


Fig. 2. Example of curve for checking precision of separation of an elutriation unit by screen analysis

reduces fluctuations of the sizes to a minimum. During the construction of the Jochenstein dam on the Danube, for instance, where elutriation units are operating with a grain dispersion κ 25/75<2, it has been shown by laboratory tests, carried out over many weeks, that the grain content above 1 mm. is subject to very small fluctuations in the class 0·1—1 mm., while the dispersion corresponding to the 2/3 probability is only about $\pm$1·5. On the other hand, the content of grains below 1 mm. in the 1—3 mm. class varies only by $\pm$3 per cent.

The above dispersion figures (calculated according to the Gauss error square method) might be calculated in practice by eliminating, from 60 analysis figures, the ten highest and the ten lowest figures. If, for instance, from among 60 screen analyses the average figures for the oversize grain content from 40 analyses is between 6·5 and 9·5, the average content of oversize grains will be 8 per cent. and the dispersion $\pm$1·5 per cent.

Guarantees that can be required at 1 mm. size

Precision of Separation: The dispersion of grains should not be above 2·5.

Tolerance of Fluctuations: The grain parting diameter (κ_{50}) should not vary more than 0·1 mm. during the running operation, which means that it should remain between 0·9 and 1·1 mm.

Precise separation is also of great advantage in eliminating dust and mica.

Low Losses of Sand: It should be required that losses of material above 0·15 mm. should be insignificant and practically all spherical grains below 0·06 mm. should be eliminated. Guarantees based upon certain limits of the contents of oversize and undersize grains, in spite of it seeming easy, are only possible in relation to a definite screen curve of the raw sand.

Constancy of Dust Content: The higher the precision of a selecting system, the less will be the content of residual dust (below 60 microns), irrespective of the dust content in the raw sand.

Optimum Elimination of Mica: A reasonably complete elimination of mica up to 0·3 mm. can be effected by an exact separating horizontal elutriation equipment within significant losses of grains above 0·15 mm.

Guarantees that may be requested for Dust and Mica Elimination by Hydraulic Elutriation: The higher the dust content of raw sand, the higher should be the precision of separation. In the majority of cases the maximum limit 3 should be required for grain dispersion; in special cases the requirement conditions should be somewhat stiffer.

REFERENCES

1 J. Fritsch. "Amerikanischer Talsperrenbau," *Schriftenreihe des Osterreichischen Wasserwirtschafsverbandes*, Wien, Heft. 24.
"Talsperrenbeton," *Schriftenreihe des Osterreichischen Wasserwirtschaftsverbandes*, Wien, Heft. 15.

2 B. W. Steele. "Lean Mass Concrete used for Interior of Dams," *Journal* of the American Concrete Institute, Vol. 22, March 1951.

3 A. F. Taggart. "Handbook of Mineral Dressing," New York, 1950, Seite 8-49, 8-52.

4 G. Rott. "Johnsonturm und Vertikalschlämmanlage beim Bau der Tauernkraftwerke AG," *Der Bau und die Bauindustrie*, Düsseldorf, Juni 1953.

5 K. Bracher. "Bericht über den Osterreichischen Betontag 1953, *Allgemeine Bauzeitung*, Wien, No. 344, S 3-5, 1953.

6 A. Wogrin. "Uber die Frostbeständigkeit des Betons," *Osterreichische Bauzeitung*, Nos. 17/18/19, 1951.

7 Th. Eder. "Die Trennschärfen verschiedener Schlämm-Methoden," *Zeitschrift für Erzbergbau und Metallhüttenwesen, Stuttgart*, 1951, Heft 4, S 137-143.
"Zur einheitlichen Kennzeichnung der Trennschärfe," *Montanzeitung*, Wien, 1951, Heft 9, S 163-165.
"Precision in Mineral Separation," *The Mining Magazine*, London, April 1952.
"Choix d'un coefficient unique pour caractériser la précision de séparation," *Revue de l'Industrie Minérale*, St. Etienne, December 1951.
"Kjenningstall for bedommelse av apprednings-Prosesser," *Tidsskrift for Kjemi, Bergvesen og Metalurgi*, Oslo, 1951, No. 10, S 186-187.

Notable Tunnel Driving

Although not related to water power, a 5½ mile tunnel which has been driven through the Rimutaka Mountains, North Island, New Zealand, is a sufficiently notable achievement to warrant mention in this journal. The tunnel in question is of horseshoe section, 15 ft. wide and 17 ft. high, and was completed in less than three years, the contract having been entrusted to the Morrison-Knudsen Company of New Zealand Limited, a subsidiary of the Idaho firm. It was begun on July 30, 1951, and was holed on April 20 this year. It was driven from the two portals only, the rock at first consisting of a very unstable graywacke, making a pilot drift desirable. This was kept well in advance of the main operations. The top heading was braced with 10 in. by 10 in. timbering as it was advanced, and as the remaining material was removed for the full-sized bore this timbering was extended, serving to keep the ground open while reinforced-concrete rings were poured between adjacent sets. The record achievement was 250 ft. of tunnelling in one week, with 208 ft. concrete lined, and the best day's driving and timbering was 47 ft. On average, the driving and timbering progressed at 42 ft. per day in spite of the fact that the entire length of the tunnel had to be timbered, instead of half, as was anticipated.

Ewbank and Partners (Canada) Limited. Mr. C. H. P. Ewbank, chairman of Ewbank and Partners Limited, London, announces that his company are setting up in Canada an associated company, Ewbank and Partners (Canada) Limited, with headquarters in Toronto. The new company will be under the general direction of Mr. J. T. Moore, a director of the parent company, and until recently chief engineer of The English Electric Co. Ltd. The Canadian company will operate in close association with Crippen Wright Engineering Limited, Vancouver, engineering consultants in the hydro and civil-engineering fields. Mr. G. E. Crippen, president of Crippen Wright Engineering Limited, was previously chief designing engineer of the B.C. International Engineering Company, and was responsible among other similar schemes for the design of the Kemano power project for The Aluminium Company of Canada. Mr. C. H. P. Ewbank has accepted a seat on the board of Crippen Wright Engineering Limited.

Testing of Switchgear. Under the title "Quality Tests," Cooke & Ferguson Limited, of Manchester, have issued a 23-page publication (No. S118) which gives a survey of the modern testing technique they apply to the various types of switchgear they manufacture.

The Salanfe-Miéville Turbines

Further to the article on the Salanfe development in our October 1953 issue. we are now able, through the courtesy of Charmilles Engineering Works Limited, to recount the technical considerations that determined the design of the Pelton turbines in Miéville power station.

By PAUL PINGOUD, Ing.Dipl. (Lausanne)

BEFORE proceeding to discuss the Salanfe-Miéville turbines it may be useful to summarise certain fundamental concepts which, in the first place, will go to justify the technical solutions adopted for the problems presented by this installation, and secondly, will provide a basis of comparison with other installations.

Specific Speed

Any turbine can be classified on the basis of its specific speed, and the relevant formula can be applied to the Pelton turbine by introducing the two quantities d, the diameter of the jet at full discharge, and D, the pitch-circle diameter of the wheel. Thus:—

$$n_s = C_1 u \frac{d}{D} \sqrt{\eta} \qquad \ldots \ldots \ldots \ldots \quad (1)$$

where

C_1 is a constant

u is the velocity coefficient $U / \sqrt{2gH}$ where U is the peripheral velocity of the wheel at pitch circle

η is the turbine efficiency.

From one turbine to another the values U and η vary very little, so that in general we may write:—

$$n_s = C_2 \frac{d}{D} \qquad \ldots \ldots \ldots \ldots \ldots \ldots \quad (2)$$

where C_2 is a new constant.

Thus Pelton turbines can be classified, with a sufficient degree of approximation, according to the ratio between the diameter of the jet and that of the wheel pitch circle.

Now, n_s is essentially a function of the head H—or more explicitly, it is the permissible value of n_s that is a function of H, its value being decided in the first place by mechanical considerations such as the space necessary for fixing the buckets, fatigue of material, and so forth. The higher the available head H the larger must be the ratio D/d and the lower must be the value of n_s.

This is a very important conclusion for the comprehension, independently of any question of general design, of the difference in behaviour of Pelton wheels of different specific speeds. We shall return to this point shortly. In the meantime we might mention that for a Pelton turbine the highest value of n_s that can reasonably be attained for a single jet hardly exceeds 36 (metric), and even this figure is only admissible for a head of less than 200 m.—a head that is well suited to the faster-running, and therefore more economic, Francis turbine. The borderline between these two types of turbine is in the region of 400 m. for units of the order of 60,000 h.p.

Behaviour of the Jet

It has long been known that Pelton turbine jets operating under high heads, and thus emerging at high velocity, have a clearly marked tendency to disperse—a phenomenon attributed partly to turbulence but mainly to air friction. In this connection we may cite the care taken, as long as 20 years ago, in the configuration of the turbine injectors at Dixence, operating at a head of 1,750 m., one of which can be seen in Fig. 1. The injector assembly was arranged in a straight line in order to avoid the distortion in the flow due to the usual elbows, which would have affected the structure of the jet by inducing secondary currents. This was an exceptional case in which it was to be expected that a lack of homogeneity of the jet might impair the bucket efficiency and even induce rapid wear. The Dixence injector constituted a great advance in the construction of Pelton turbines. In spite of a bifurcation in the pipeline a little way back from the jet to accommodate the spear

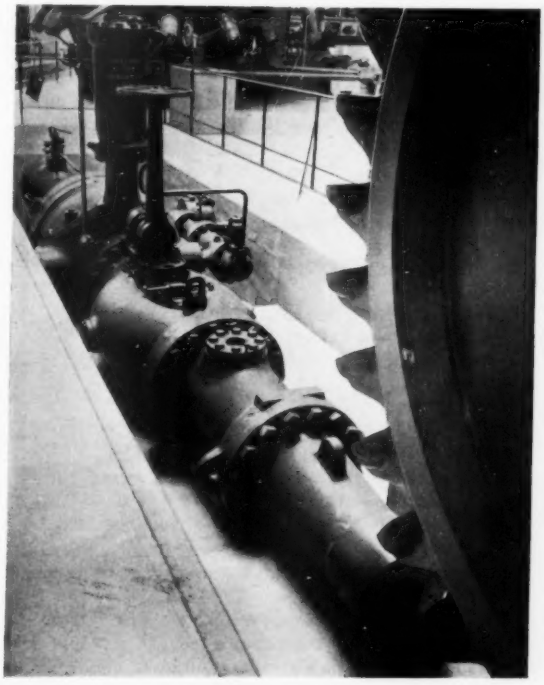


Fig. 1. One of the turbine injectors at Dixence

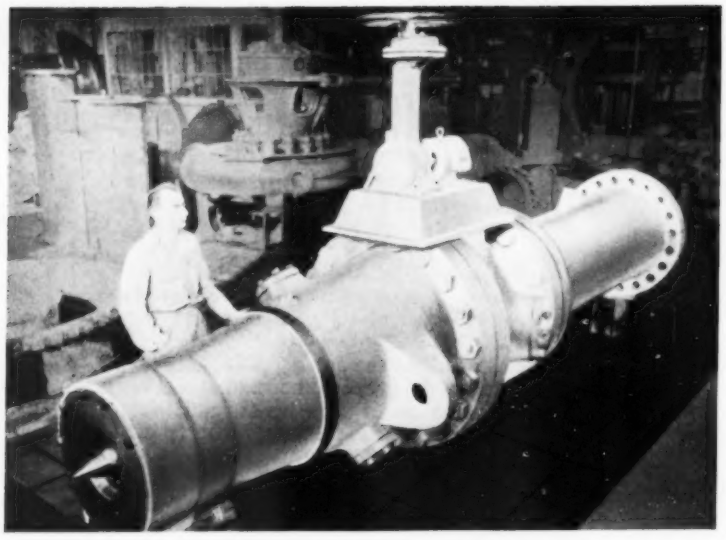


Fig. 2. Straight-flow injector for Miéville

mechanism, it had the merit of being symmetrical with respect to the plane of the wheel.

Later, the phenomenon of jet dispersion was the subject of a detailed study by P. Oguey, formerly Professor at l'Ecole Polytechnique, Lausanne, and his two assistants, M. Mamin and F. Baatard—a remarkable and lengthy piece of work and one worthy of respect, for it reached precise and quantitative conclusions of immediate practical interest. It is now established that the dispersion of a jet depends—to quote the authors—"essentially on turbulence, this being a function of the head and the hydraulic system preceding the orifice, whereas the resistance of the air can be neglected over the section of the jet that can be utilised by a Pelton wheel except at the surface of a jet of small discharge where the drops are sufficiently separated to be influenced by the braking effect of the air." As the degree of turbulence is characterised by the Reynolds number, the same study confirms that the dispersion increases not only with the velocity of the jet but also with its diameter.

An Important Aspect of the Behaviour of the Jet in the Wheel

The simplified relationship (2) shows that for a Pelton wheel the higher the specific speed the lower becomes the ratio of wheel to jet diameter. A simple diagram would show that in these conditions the total angle α swept by a bucket in passing through the jet increases with the specific speed. On measuring this angle on the pitch circle in the plane of the wheel it is found that:—

$$\cos\frac{\alpha}{2} = 1 - \frac{d}{D} = 1 - \frac{n_s}{C_2}$$

Now, except for alterations required by the variable behaviour of the liquid particles operating in the buckets, it is obvious that the design as a whole can only be worked out for a definite position corresponding to maximum efficiency. In other words, the Pelton turbine is essentially a cyclic-flow machine, and this immediately explains why a larger zone of imperfect impact (α greater) must imply a less favourable mean efficiency.

Pelton Turbines for Very High Heads

When one speaks of a Pelton turbine for very high head one uses a term that is ill defined but that generally signifies a head exceeding 1,000 m. For reasons already explained the specific speed is fairly low. From the preceding paragraphs we can now draw some general conclusions as follows:—

(a) Seeing that the jet velocity is very high it is essential to develop injectors specially designed to impart a good internal structure to the jet so as to reduce the tendency to dispersion as far as possible.

(b) A high head necessitates a large wheel diameter, and in consequence the injector nozzle has to be placed at some distance from the point at which its centreline makes a tangent with the pitch circle. This militates against the compactness of the jet as it reaches the bucket, since dispersion increases with length of travel from the jet. This constitutes an added reason for constructing injectors capable of producing jets with a particularly good internal structure.

The increase in wheel diameter also involves an increase in ventilation losses—a complex question on which we will not delay here.

(c) On the other hand, the angle α swept by the buckets in passing through the jet is appreciably smaller in very high-head Pelton wheels, and this partly compensates for the two drawbacks just mentioned.

(d) Turning now to a more general conclusion, from the standpoint of the best possible performance, extreme values of specific speed are the least favourable, but for different reasons. Experience has

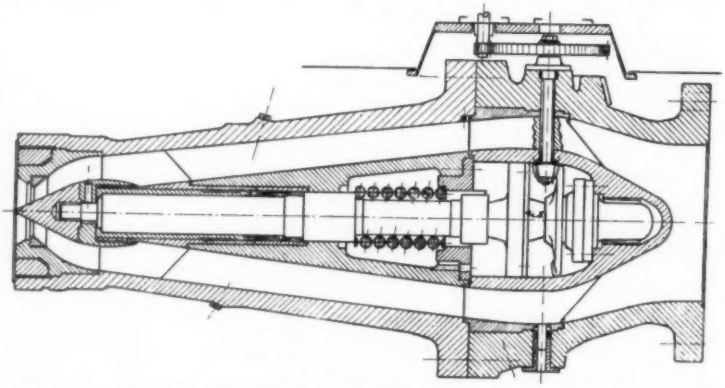


Fig. 3. Longitudinal section through Miéville injector, showing internal casing housing the needle-control mechanism

effectively confirmed that the best Peltons have a specific speed of 16 to 17 (metric), which is pretty nearly a mean value between the extremes found in practice.

The justification for this long general introduction, in advance of the description of the Salanfe-Miéville turbines, lies in setting out the essential elements of the purely hydraulic problems that had to be resolved to the best advantage in this particular case. In fact, owing to the entire success of the earlier installation at Dixence the Charmilles Engineering Works Limited were confident in proceeding to the design of the Pelton equipment for all the higher-head plants subsequently undertaken. These include the installations at Portillon consisting of a 55,600 h.p. unit operating at a head of 1,304 m., and a 48,200 h.p. set under a head of 1,030 m. for Fond de France, both of which were manufactured in collaboration with Alsthom, the two 12,650 h.p. turbines to the Los Molles station in Chile working at 1,125 m.—the highest head utilised in the whole of the American continent—and finally the three 31,000 h.p. units of the Reisseck plant* in Austria with a net head of 1,770 m., beating the record previously held by Dixence with a head of 1,750 m.

Characteristics of the Salanfe-Miéville Turbines

Each of the Salanfe-Miéville turbines is designed to satisfy the following conditions:—

Net head ...	m.	1,321·0	1,348·0	1,447·4
Discharge ...	cu. m./sec.	2·67	2·7	2·8
Power	h.p.	41,500	43,000	47,800
Operating speed ...	r.p.m.	500	500	500
Runaway speed ...	r.p.m.			930

The head given in the centre column is that for which the turbine gives its best mean efficiency, and corresponds to a specific speed of 12·7.

* See WATER POWER, February 1954, page 55.

Each set is of the horizontal-shaft type and is carried on two bearings only, the Pelton wheel being overhung at one end of the alternator shaft. In order to bring the bearing on the turbine side as close as possible to the wheel, it is supported on a bracket cast integral with the turbine casing. This bearing is provided with a thrust collar which serves mainly to centre the shaft, since theoretically a Pelton wheel does not exert any end thrust.

Seeing that the turbine incorporates a single injector, it is characterised by a considerable power concentration in a single jet. Nevertheless the jet is not very big, as it is only 148 mm. in diameter at full discharge.

It is interesting to compare one of the Miéville turbines with one of those at Dixence. The unit output of the latter is slightly higher, but is developed from a higher head, so that the problems are analogous. However, when the Dixence station was built it was thought preferable, for each set, to divide the discharge over two wheels overhung on either side of the alternator, each provided with a single injector. It was considered that for high heads the use of two jets per wheel should be avoided because for the same specific speed this would involve multiplying the frequency of the jet impacts on each bucket by 2·8, and would correspondingly reduce their life. Further, in 1932, when these turbines were ordered, electrical engineers preferred to limit the speed of the generator to 500 r.p.m. For the construction adopted it automatically followed that the value of the specific speed, for each jet, fell to 7·2. From this standpoint the Miéville turbines should be capable of a still better hydraulic performance.

From the constructional standpoint, also, the wheels at Dixence differed from those at Miéville. The Dixence wheels consist of a disc having a groove cut in its periphery into which the dovetailed lugs of the buckets are successively slid and secured by a lock

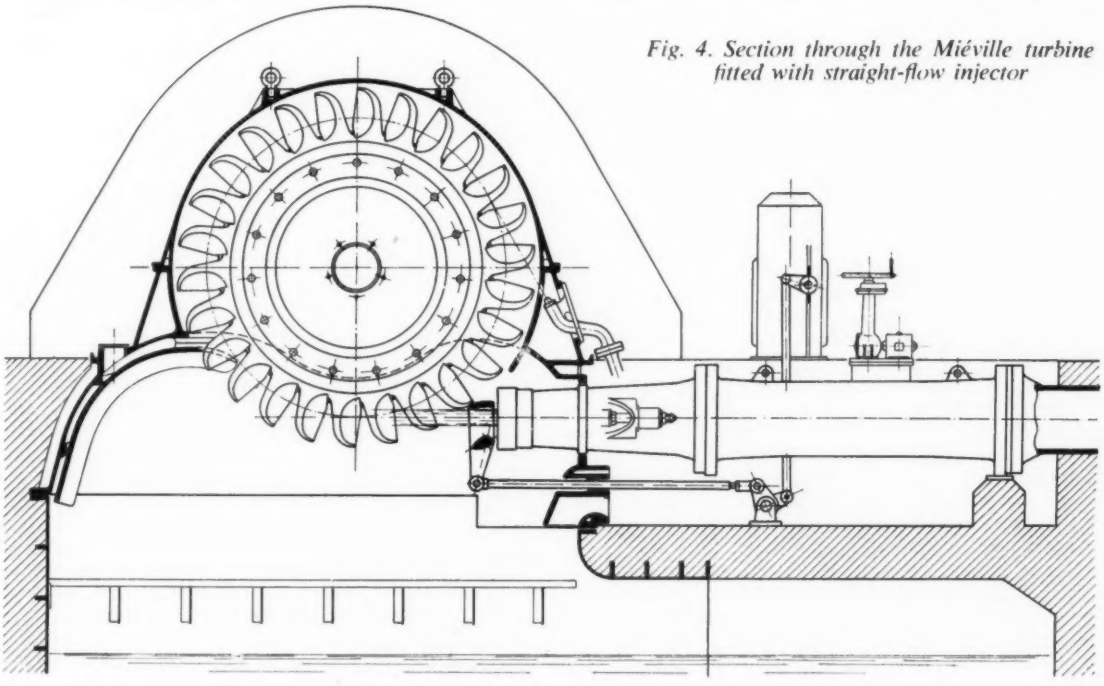


Fig. 4. Section through the Miéville turbine fitted with straight-flow injector

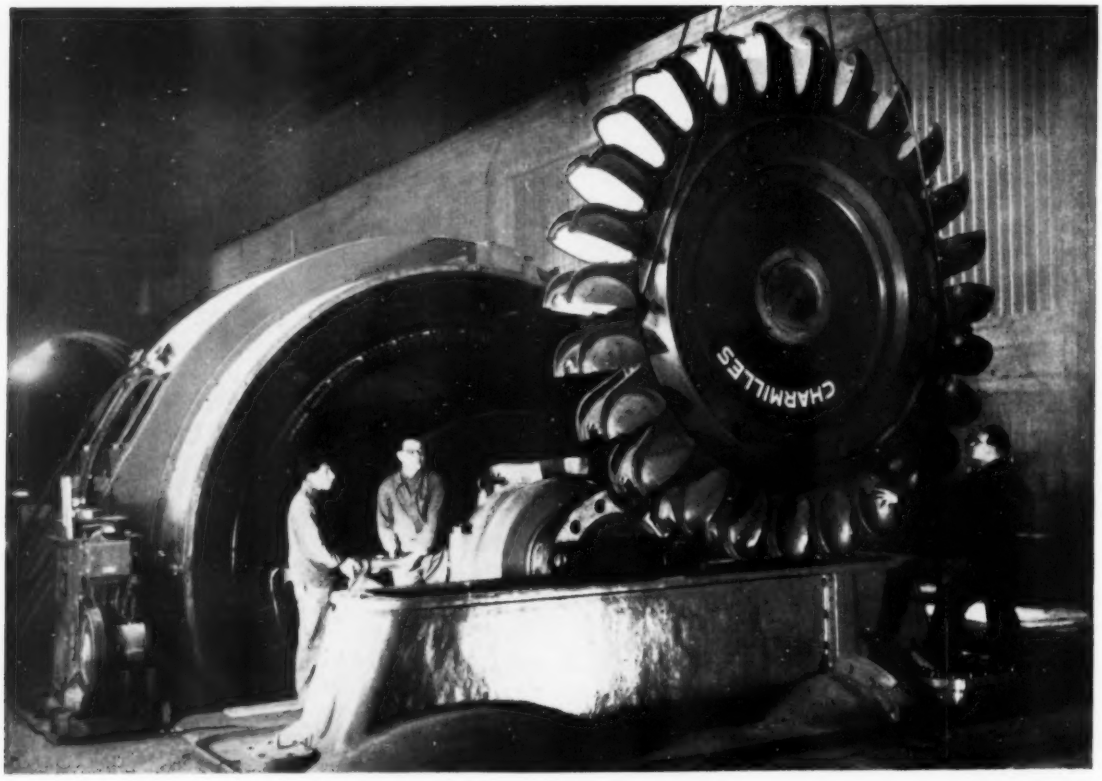


Fig. 5. Assembling one of the 47,800 h.p. Charmilles turbines at Miéville

at the end of the operation. These buckets are clamped by a shrink fit obtained by heating the disc before final assembly, and by transverse keys between the buckets which serve also to transmit the force of the jet to the bucket-wheel assembly.

At Miéville, thanks to progress made by the steel-founders, the wheel consists of a ring of stainless-steel buckets cast as one piece and of a central cast-steel disc. The bucket ring is clamped to the periphery of the disc by a mating ring which engages a circular spigot on the bucket ring and grooves in the central disc by means of a taper fit. The disc and clamping ring are so dimensioned that in the event of fracture of the bucket ring they can hold the buckets in place without excessive fatigue, thus affording an increased measure of safety. As a supplementary precaution three transverse keys, parallel to the bolts already mentioned, prevent the bucket assembly from sliding around inside the grooves. It should not be forgotten that each bucket is subjected to a force that may reach 29 tons, at the rate of 25 times every three seconds. It is therefore essential for the parts of the wheel assembly to form an unshakably solid structure. Between each successive jet impact the bucket is subjected to a tensile stress by centrifugal force, which passes abruptly to compression along the back of the bucket due to the bending moment imposed by the force of the jet. One can visualise the precautions that must therefore be taken to avoid the speedy destruction of materials exposed to such merciless treatment.

In addition to this hammering the buckets have to withstand the erosive action of a jet the absolute velocity of which may reach 163 m. per sec. This points to the importance of securing satisfactory flow conditions within the bucket so as to avoid local separation likely to engender corrosion. To achieve this result the buckets must be carefully formed, machined and polished. This assumes that the steel-works is able to deliver a rough casting in which the profiles are everywhere exact. Further, the metal must be free from porosity, as otherwise it would be rapidly attacked by cavitation. Often such defects cannot be discovered during machining and polishing, as these operations have the effect of "soaping" the internal surface of the bucket, and Pelton wheels for very high heads should therefore be examined, touched up and welded where necessary, some little time after being put into service, and subsequently they will give long service and will stand up to normal wear.

Of the three Miéville turbines two have a bifurcated injector similar to that at Dixence, as seen in Fig. 1, whereas the third has a straight-flow injector in which all the passageways, except for the guide vanes, are surfaces of revolution, so that in every section the injector is absolutely symmetrical with respect to its longitudinal centreline, which coincides with that of the jet (see Figs. 2 and 3).

To achieve this design the injector incorporates an internal casing containing the entire needle-control mechanism. This involves the use of a high governor-oil pressure and the design of joints and packings that are perfectly tight against the entry of water from the surrounding space.

This design has proved entirely successful, and it

has been a most interesting experiment to have been able, in the same plant, to install it on one turbine whereas the others, as stated above, incorporate bifurcated injectors which have already proved their worth. When the turbines have operated for long enough it is hoped to establish the improvement in the life of the material brought about by installing a mechanism so eminently suited to reduce jet dispersion.

The construction of the turbine fitted with a bifurcated injector can be seen from the cross section in Fig. 4. Seeing that the jet acts to some extent as an ejector a ventilating hole has been arranged below the injector to aerate the casing.

The governor is of the speed-acceleration type which has not the drawbacks inherent in purely speed governors furnished with temporary compensation gear. In addition to the linkage between the governor distribution valve and the needle servomotor there is a linkage to the deflector so arranged that whatever the load on the turbine, and consequently whatever the diameter of the jet, the edge of the deflector is always closely tangential to the jet and is ready to come into action with all necessary speed.

Governor oil is supplied by two pumps, one of which, for starting and emergency service, is supplied from the station auxiliary supply, whereas the other, for normal operation has its own connection with the small pilot alternator feeding the motor of the governor. Finally, a small hand pump enables the deflector to be withdrawn in the event of a failure of the auxiliary supply and the turbine to be started after opening the needle by a hand gear.

Governor adjustments, such as change of speed and limitation of needle opening, can all be carried out either manually on the spot or at a distance by means of small electric motors. All indications of amount of opening of deflector and needle, position of load limiter, oil and water pressures, and remote-control pushbuttons are clearly arranged on a control board.

Furthermore, this governor is equipped with various safety devices of which we shall only mention the chief. The accidental stopping of the oil pump automatically lowers the deflector under the action of a safety cylinder maintained constantly under the full water pressure, which is normally counteracted by the oil pressure, this oil pressure being released by the operation of any protective device. The attendants can then proceed to place the emergency pump in operation so that service can be restored.

In the event of a runaway, an astatic centrifugal governor, driven by the motor shaft, brings about the rapid lowering of the deflector in the manner we have just described, as soon as the speed exceeds a predetermined value.

Finally, a fault in the pilot alternator, for instance by loss of excitation, involving a reduction in voltage on the terminals of the pendulum motor, will be detected by a minimum-voltage relay. A contact on this relay energises an electromagnet through the auxiliary supply, which opens a valve releasing the oil pressure. Thence the shutdown procedure is the same as previously, but in this case only proceeds to the idle-running position.

Thus, in the choice of the method of operation of the safety devices it has been borne in mind that security of service is often on a par with the simplicity of the mechanism designed to attain it.

Quebec Power Company

Net income of $1·57 per share in 1953, compared with $1·28 the previous year, was shown by Quebec Power Company when its annual report was issued recently. Gross revenues last year were $9 million—an increase of 9·7 per cent. over 1952. Commenting on this Mr. J. A. Fuller, the president, stated that gross revenues had more than doubled since the end of the war, and nearly trebled since 1939. This increase he attributed largely to greater sales of electricity, which now accounted for 91·6 per cent. of revenues. While the company's residential customers for electricity had doubled in number since the beginning of the war, he added, their average annual use of it had more than trebled. During this time, however, the average price paid per kilowatt hour had decreased by almost one-half, due to rate reductions and the greater average use per customer.

Net income last year, after providing for bond interest and income and profits taxes was $871,252, representing an increase of 22·7 per cent. compared with 1952. Of the gross revenues, 11·2 per cent. came from industrial consumers using high-voltage power—this category of electricity sales showing the greatest increase—while 44·8 per cent. came from other industrial and commercial consumers, 32·5 per cent. from residential users, and 3·1 from farmers. Electricity sold totalled 616·5 million kWh, a 9·6 per cent. increase over 1952, and the system peak load rose 9·5 per cent. to 149,175 kW. The number of customers served, at the year's end, was 99,266, an increase of 4,056 over the year before, and the average consumption of electricity per residential customer rose 11 per cent. in 1953 compared with 1952.

A Bhakra-Nangal Special Issue. Readers who would like further information on the Bhakra-Nangal development are referred to a special Bhakra-Nangal Number published by our contemporary *Indian Journal of Power and River Development*. The issue runs to 144 pages of text, and contains individual articles on every part of the development. It can be obtained from the publishers at 6, Waterloo Street, Calcutta 1, at Rs. 5.

Turbine Gear for Mullardoch. In our description of this installation published in our March issue we were under a misapprehension in stating that the gear and generator were located at the top of the access shaft. Actually the entire plant is situated in a chamber at the foot of the shaft, and at present the controls are also located in this chamber. The surface building houses a monorail crane, batteries, and the inlet-gate winch. The references in the article to Loch Affric should, of course, read as Loch Mullardoch.

Consolidated Compressors. An attractive brochure received from the Consolidated Pneumatic Tool Co. Ltd. illustrates and gives full technical data of their new portable C.P. compressor, Model 315, which is powered by a 93 h.p. Rolls Royce 6-cylinder diesel engine.

Model Technique for the Solution of Water-Hammer Problems

D. W. Kingdon, B.Sc.(Eng.), A.M.I.Mech.E., describes some research carried out in the laboratories of the Battersea Polytechnic, London.

A LARGE number of books and papers have been written on the subject of water hammer and the theory of the phenomenon is now well developed. In fact the water-hammer pressures which will be produced in any given conditions can be predicted very accurately by the application of this theory. However, in most practical cases where there is any degree of complication the calculation of water-hammer pressures becomes very laborious, and although the graphical methods, which have been developed mainly by Schnyder and Bergeron, have helped to reduce the labour of computation, even these methods will frequently be found cumbersome when dealing with the more complex hydraulic systems.

The designer of such systems is often faced with the necessity to explore several alternative layouts. When a number of different operating conditions must be examined for each layout, as is often the case when checking water-hammer pressures, the designer is in need of a suitable tool to speed up his work. A model technique for this purpose is proposed in this article and some work done by the author towards its development is described.

Theoretical Basis

The basis of the proposed technique is the graphival construction developed by Schnyder and Bergeron[1] and others[2, 4]. If a diagram is constructed for given water-hammer conditions in a full-scale pipe system, it is evident that the same diagram, but with different scales of pressure and velocity, could represent "similar" water-hammer conditions in a pipe system of smaller physical dimensions (these dimensions being suitably chosen).

The necessary conditions for similarity are:—

(a) Equal values of the Allievi pipe characteristic:—

$$\frac{a V_o}{2g H_o}$$

where

a = Wave velocity, feet per second.
V_o = Velocity in pipeline during the initial steady flow.
H_o = Elevation in feet of the free water surface above the valve.

(b) Similar boundary conditions.

If these conditions are met, one pressure-time curve can be drawn which will represent the "similar" transients in both the full-scale and the model systems, provided that suitable pressure and time scales are applied for the full-scale system on the one hand and different scales for the model system on the other hand.

To satisfy condition (a), if the symbols a, V_o, H, etc., refer to the full-scale pipe system and a', V_o', H', etc., refer to the model, then

$$\frac{a V_o}{H_o} \text{ must be equal to } \frac{a' V_o'}{H_o'}$$

i.e. if a' and H_o' are fixed to suit the model system, V_o' must be adjusted to give the correct value to the characteristic.

Also to satisfy condition (b), if t and t' are the times during which the flows in the full-scale and model systems are altered (e.g. in a typical case times of opening or closing of a valve):—

$$t \times \frac{a}{L} \text{ must be equal to } t' \times \frac{a'}{L'}$$

where L and L' are corresponding length dimensions in the two systems.

Since $H_{max} = \frac{a V_o}{g}$ and $H'_{max} = \frac{a' V_o'}{g}$

the pressure-scale ratio is given by: $\frac{H}{H'} = \frac{a V_o}{a' V_o'}$

Also the time scale ratio is given by: $\frac{t}{t'} = \frac{a' L}{a L'}$

Work Necessary to Develop the Method

The pressure fluctuations produced in laboratory-scale pipe systems are of very high frequency, and the method of recording the pressure-time curves must be suitably chosen. The cathode-ray oscillograph is the obvious choice of instrument, and permanent records of the transients can be made photographically. A capacity-type pressure-sensitive device was used in the experimental work described later, and in most cases appeared to give satisfactory results. (For a description of this type of pick-up see Ref. 3.)

Methods of controlling the boundary conditions in the models must be developed, and to this end a spring-operated quick-acting valve with dashpot to control the time of closing was constructed. Further development of this apparatus would be required for experimental work intended to test the design of full-scale plant.

The first step in the use of the model apparatus must be to compare actual pressure-time records with the graphs derived from the experimental conditions on theoretical grounds. Some work on these lines was carried out as described later.

A further necessary step before predictions can be made with confidence is the comparison of records of water hammer in full-scale pipelines. The author believes there is a good case for the careful recording of water-hammer transients in large pipelines wherever possible and the widest publication of the data.

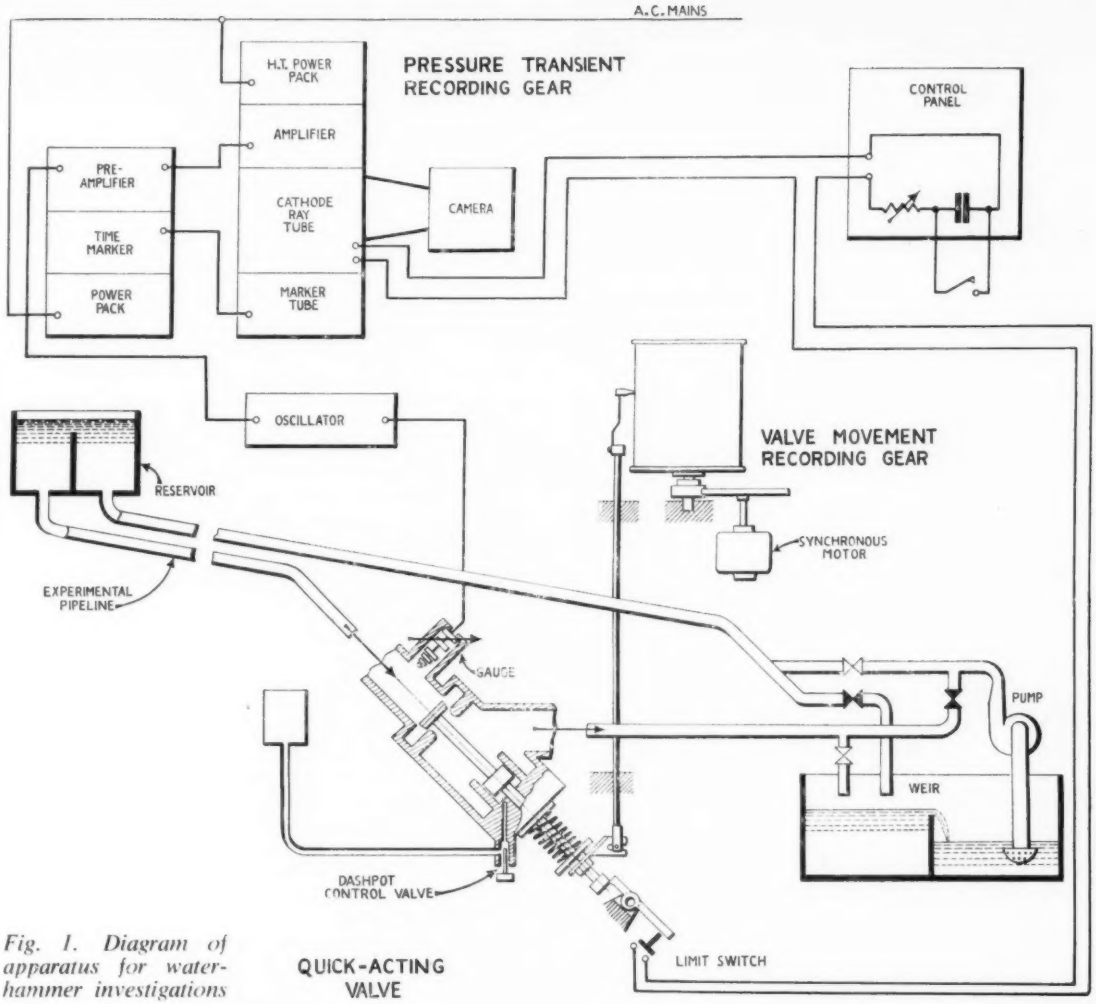


Fig. 1. Diagram of apparatus for water-hammer investigations

Description of Apparatus

The hydraulic system and recording gear is shown diagrammatically in Fig. 1.

The experimental pipeline was connected at its upper end to a tank acting as a constant-level reservoir, and at its lower end to a quick-acting valve. Both upward and downward flow could be obtained in the experimental pipeline and by adjusting the valves shown a constant level was maintained in the reservoir in each case.

The quick-acting valve was spring loaded and held in the open position by a rapid-release catch acting on a collar whose position on the valve spindle was adjustable, thus allowing the valve stroke to be altered. The closing movement of the valve was controlled by a dashpot, the rate of closure being adjusted by throttling the release of water from this dashpot.

The pressure pick-up formed a part of the capacity of an oscillatory circuit, so that variations in pressure caused variations in the frequency of oscillation in this circuit. The oscillator was housed in a separate box connected by a short lead to the pick-up. The frequency-modulated output of the oscillator was fed to a pre-amplifier in which this signal was converted to one of varying voltage. This was again amplified before being applied to the Y-plates of the cathode-ray oscillograph. When producing permanent records by means of the camera supplied with the apparatus, only the Y-plates were energised, the X-component of the trace being supplied by the movement of the rotating drum to which the strip of photographic recording paper was attached. The image of the "spot" on the cathode ray tube screen was focussed on to the photographic paper by means of a lens, the whole optical system being enclosed in a lightproof casing.

The time base was marked by means of an auxiliary cathode-ray tube in which the spot was given a rapid deflection and return at fixed intervals. This was achieved by a separate oscillatory circuit held to constant frequency by a tuning fork.

A drum carrying recording paper was driven at constant speed by synchronous electric motors connected to the main supply system. A stylus was made to bear against this drum, and guided to move in a direction parallel to the axis of the drum. The arm carrying the stylus was connected through an inclined-plane mechanism to the valve stem, so that its dis-

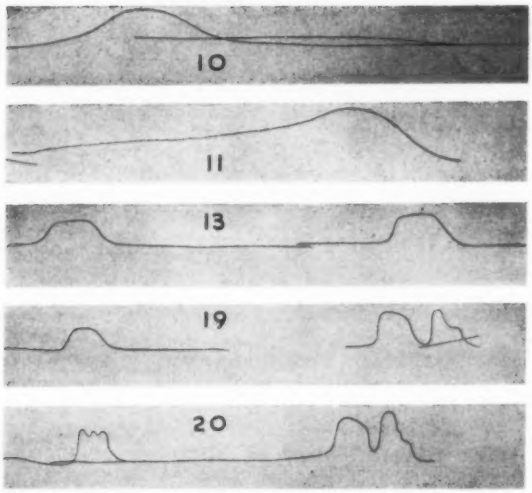


Fig. 2. Typical records obtained with the apparatus outlined in Fig. 1

placement was exactly proportional to the displacement of the valve. Thus the displacement-time curve for the valve was drawn automatically on the recording paper.

Initiation of Recording

The release of the catch set in motion all the events necessary for recording a pressure surge in the pipeline. Thus the valve closed under the control of the dashpot and recorded its movement on the paper attached to the revolving drum. At the same time a limit switch was closed by the movement of the arm of the release catch. The switch closed an external circuit across the trigger terminals of the cathode-ray oscillograph, the effect of this being to bring the beam on to the screen of the cathode-ray tube. The circuit also contained a condenser and variable resistance so that after a period of time a voltage was built up across the trigger terminals and the beam was again extinguished. This interval was adjusted to coincide approximately with the time taken by the camera drum to make one revolution.

Two series of tests were carried out:—

(a) With a simple experimental pipeline as shown in Fig. 1.

(b) With this pipeline modified by having a branch pipe with a closed end connected at its midpoint.

In each series the other variables which could be altered were adjusted over as wide a range as the available apparatus permitted, but two main types of record were obtained, viz:

(i) Those in which the quick-acting valve was closed in less than one interval $\frac{2L}{a}$

(ii) Those in which the time of closure was several times this interval.

Individual Tests

No. 13 was a typical test of the type (a) (i): the Schnyder-Bergeron diagram and the derived pressure-time diagram for this test, based on the observed conditions, and compared with the recorded transient are shown in Fig. 3. The main differences between the theoretical and recorded diagrams lie in the smaller rate of pressure rise in the former as compared to the latter, and in the pressure peak which occurs in the recorded diagram just prior to the drop to normal pressure, but which is absent in the theoretical diagram. The difference in rates of pressure rise is probably accounted for by a wrong estimation of the effective time of closure of the valve; the method of recording of the time of closure was not sufficiently refined to give great confidence in its accuracy. With regard to the pressure peak, Binnie (Ref. 3) has shown that peaks in the tops of such diagrams correspond in position on the diagram to the position of bends, etc., along the length of the pipeline. In this case the peak occurs close to the commencement of the fall in pressure on the diagram corresponding to the position of a 90° bend in the experimental pipeline near to the reservoir. The reflected pressure waves from this bend may be assumed to account for the rise in pressure above the Joukowsky value shown in the cathode-ray oscillograph record. After the first pressure surge the water rebounds from the closed valve, and the pressure drops below atmospheric as the column of water in the pipe parts company with the valve. The second pressure surge which occurs when the column of water falls back on to the closed valve was also recorded in this test. The maximum pressure attained under the conditions of this test should be that given by the Joukowsky formula $h = \frac{aV_o}{g}$ and in this case there is quite close agreement.

In Test No. 10 the valve was again closed in less than one interval but in this case the flow was towards the reservoir, i.e. the effect of pump failure on a pumping main with resultant rapid closing of a check valve in the main above the pump was simulated. The widely different effects which may be produced by various sets of conditions in this situation have been explained by Bergeron (Ref. 1). The recorded data in this experiment do not permit a precise theoretical treatment but it may be stated that a

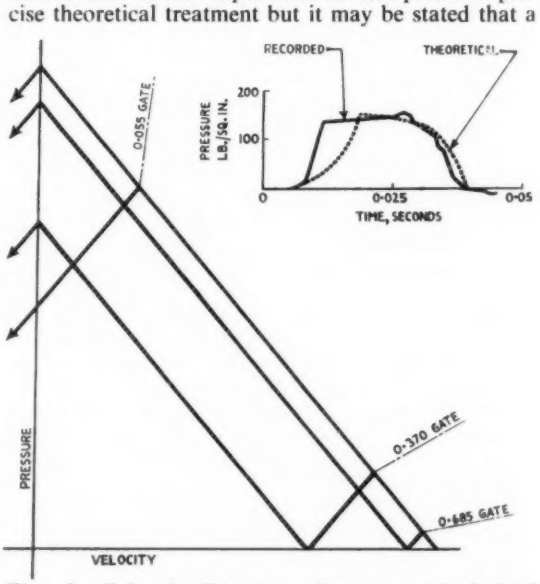
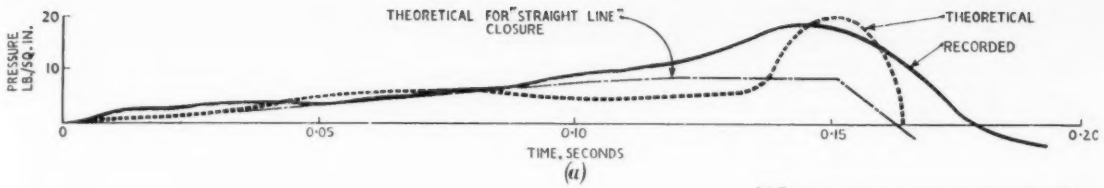


Fig. 3. Schnyder-Bergeron diagram and derived pressure-time diagram



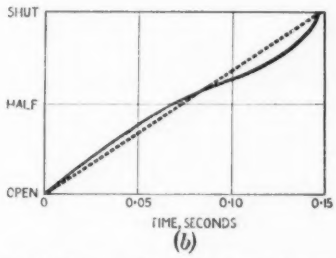


Fig. 4. Comparison of theoretical and recorded diagrams for Test 11. Diagram (b) shows the corresponding curves of valve movement

maximum pressure considerably below the Joukowsky value was to be expected, as in fact was recorded.

Tests 11 and 12 were intended to represent the conditions which may be permitted to occur in a turbine penstock in an emergency, and for which the penstock must be designed. Closure is in six and ten 2 L/a intervals respectively and the maximum pressures generated are around 20 lb. per sq. in. in each case. The closure law is not straight line as in Test 13, but is more rapid at the beginning and end of the stroke than in the middle. The theoretical diagram is shown in Fig. 4, and the theoretical diagram for straight line closure in the same time as the actual closure is also shown, and it will be seen that the comparatively small change in the closure law results in at least 100 per cent. increase in pressure rise. This is, of course, a typical example of the effect of the slamming of a valve.

In Tests 19 and 20 valve closure was effected in less than one pipe interval, and the branch with closed end has a very definite effect on the pressure-time diagram. The theoretical and recorded pressure-time diagrams are compared in Fig. 5. There is fairly close agreement as to the first and second pressure maxima, the first being close to the Joukowsky value, but the slope of the initial pressure rise is smaller in the theoretical diagram than in the cathode-ray oscillograph record. (Cp. Test 13.) The well known fact that a branch pipe with closed end aggravates water-hammer pressures under these conditions is illustrated here both in the theory and experimentally.

In most of the tests the friction head was two to three feet, and as a friction head of this order would have little effect on the computation of the water-hammer pressures by means of the Schnyder-Bergeron diagram friction was neglected in making these computations.

The experiments described were intended as preliminary work to explore the possibilities of laboratory models, and it is evident that many improvements could be made in the apparatus and methods employed. One of the most obvious is the simultaneous recording of the valve movement and the pressure variation in the pipeline on one and the same photographic record. This could be achieved by using a second oscillograph tube, the beam being controlled by the movement of the valve spindle through a suitable electrical system. At the same time this method would ensure an increased accuracy of recording the valve movement, which the results of the experiments described show to be necessary.

Conclusions

There should be little difficulty in reproducing on a laboratory model most of the water-hammer effects met with in full-scale pipelines, and in recording them

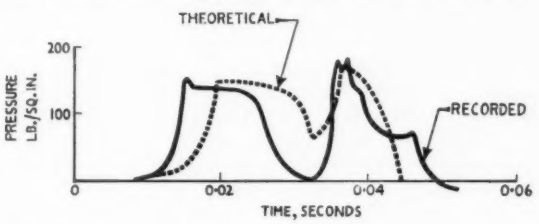


Fig. 5. Comparison of theoretical and recorded diagram for Test 19

accurately. The correlation of model test results with records of water-hammer pressures in full-scale counterparts is a prerequisite to the use of the model apparatus for the prediction of water-hammer pressures under various conditions in new construction.

Acknowledgement

The author is indebted to Professor V. C. Davies, B.Sc. (Eng.), M.I.Mech.E., of the Battersea Polytechnic, under whose supervision the work was carried out, for much help in the preparation of the hydraulic apparatus. The work was carried out on behalf of the British Hydromechanics Research Association, and Mr. P. Linton, B.Sc., A.M.I.Mech.E., of that organisation, obtained the cathode-ray-oscillograph apparatus and contributed help and advice in its use.

LIST OF REFERENCES

[1] Bergeron. "Du Coup de Bélier en Hydraulique au Coup de Foudre en Electricité." 1950.

[2] Angus, Professor R. W. "Water Hammer in Pipes, including those supplied by Centrifugal Pumps: Graphical Treatment." *Proceedings of the Institution of Mechanical Engineers*. November 1937, p. 245.

[3] Binnie and Thackrah "Water Hammer in a Pumping Main and its Prevention." *Proceedings of the Institution of Mechanical Engineers*." 1951, Vol. 165, p. 43.

[4] Stepanoff, A. J. "Elements of Graphical Solution of Water Hammer Problems in Centrifugal Pump Systems." *Transactions of A.S.M.E.*, Vol. 71, No. 5, July 1949, p. 519.

Hydro-Electricity and Fish

On all rivers in which hydro-electric developments interrupt the free passage of migratory fish, adequate steps have to be taken to preserve stocks; this article describes what is being done in Scotland not only to preserve stocks but also to augment them.

THE preservation of fish stocks has been a cardinal point of hydro-electric policy in Scotland since the earliest days of the North of Scotland Hydro-Electric Board. The stage has now been reached at which the Board is concerned to improve stocks rather than merely to preserve them. When it is remembered that their activities involve many of the important spawning areas, the value of this work cannot be over-estimated.

The work which has been going steadily forward can be outlined under several headings. There has been firstly, the provision of fish passes or lifts wherever dams or other barriers have been created. Secondly, there has been a development of areas previously impossible of access, as in the opening-up of the Lochy, and certain areas of the Conon Valley. These waters, which were previously impeded by natural barriers, have now been made available to incoming fish, and this in the process of normal hydro-electrical development. Coincidental with this policy there has been a determined and highly successful elimination of predatory types; these would normally prey on the commercial stock and seriously reduce the productivity of the waters involved. The very substantial clearances which have been recorded make it safe to claim that future resources and future catches must of necessity be much heavier than could otherwise have been the case.

The fourth main approach has been in the creation of hatcheries, located at strategic points, to feed into groups of adjacent lochs. It is again a safe claim that but for the existence of the Board and its current and prospective work in these areas, no hatchery on this scale would have been instituted.

The hatcheries are of particular interest and deserve particular mention. The Invergarry hatchery is regarded as possibly the most modern in the world, and it is surely an interesting side issue of hydro-electric development that advanced researches should be conducted into the operations of the salmon industry.

Built at a cost of £60,000, the Invergarry hatchery is designed to preserve the stock of salmon in the rivers affected by the Garry and Moriston schemes. At Loch Poulary in Glen Garry a heck or artificial barrier has been constructed to hold the fish, and there is a further barrier near Ceannacroc in Glen Moriston. Eggs are held in the Invergarry hatchery for 3 to 5 months for hatching, and the salmon fry distributed at suitable points throughout the area. These arrangements went into operation in November 1953, and just over one million eggs were obtained from the trapped fish and sent to the hatchery.

The mechanical heck is 295 ft. long and 14 ft. high, and is constructed of iron bars spaced at intervals 1§ in., the plan of the heck being in the form of a rather flat "V" pointing upstream, so that ascending fish swim into the trap at the apex. Location is at the upper end of Loch Poulary, so that over the summer and autumn the fish may use an area that is free from disease and predators, and may be held there until ready for stripping.

A false floor to the trap at the apex of the heck is raised by a windlass to bring the fish to the surface to be stripped. To prevent the crowding of the heck with every rise of water over the summer, an electric fish screen is located about a quarter of a mile downstream. This screen was designed by Mr. N. G. Lethlean, of the electrical staff of the Hydro Board, and is again an interesting example of a new development deriving from the primary objective of power supply. The electrical stop functioned perfectly throughout the summer, and it was not until the beginning of October that a very heavy flood put it out of action, and this only for one day. Current was cut off in mid-October to permit the ascending fish to reach the immediate vicinity of the trap.

A rather different arrangement has been applied at Glen Moriston. With no loch available for holding purposes the fish are held in a large pool, and stopped by a vertical concrete dam about 12 ft. high, which they cannot circumvent under any water condition. The trap is at one end of the dam, and when fish are wanted for stripping water is directed through this trap.

Stripping the fish is work which has now been organised to a point where extremely fast and efficient work can be done. Landing nets are used to take the fully "ripe" fish to a shed adjoining the trap. There the eggs are extruded from the females by pressure and fall into a basin, milt from the male then being extruded over them. They are stirred and left without water for ten minutes until fertilisation is completed; the eggs are then washed, placed in cans and transported to the hatchery. The female fish contain from 500 to 600 eggs for each pound of gross weight, and each male enough milt to fertilise the eggs from two to three females. Most of the males die shortly after spawning, and although the majority of the females survive to reach the sea, it is believed less than 10 per cent. recuperate sufficiently to return again to fresh water.

The Invergarry hatchery, which is designed to take eight million eggs in the first half of the season, uses two decks of incubating troughs instead of the normal single deck. Experience proved so satisfactory that in the second half of the season, completed in the autumn, a three-deck system of troughs was adopted. The lower layers are illuminated by lights on the underside of the upper troughs, while the topmost deck is reached from a small transportable platform. Special plastic grilles have been designed to replace the glass-rod grilles which were previously used to hold eggs in hatcheries. These glass rods were in turn

an improvement on the use of gravel beds. The single-unit plastic frame grille takes 13,000 eggs, and these are set, eight to a trough, in concrete troughs painted internally with bitumen. There are altogether 360 troughs in the layout. The incubation period varies from 90 days at 45°F. to 160 days at 34°F. For some 36 hours after they have been fertilised the eggs can be moved without danger, but after that period they must be kept perfectly still until the black "eye" spots of the developing embryo show in the egg. The hatched fish (known as alevins) live for four weeks on the contents of the yoke sac attached to the underside of their bodies, and just before this is exhausted the fry are moved by lorry to a suitable point in the glen from which the eggs were taken.

A hatchery has been completed at Contin to take eggs from a trap in the River Blackwater above Loch na Croic, which is now under construction, and will in due course help to maintain and expand the river stocks. Re-stocking of the new waters has been going on steadily since the Board first began this work. Loch Faskally, which was formed when the Pitlochry dam was completed in 1951, has had something like 17,800 yearling trout and 2,500 two-year-olds fed into it, and other reservoirs have been fed regularly. Loch Trasan in Cowal has been given 2,500 yearling trout and 6,000 fry for two years in succession.

Glen Lussa in Kintyre has had 2,500 yearlings and 5,000 fry for two years in succession. Storr Lochs reservoir in Skye got 1,000 yearlings and 500 two-year trout. Re-stocking and hatching are concentrated essentially on salmon, sea trout and brown trout.

Lochs Tarsan and Lussa are each to be re-stocked again shortly with 3,000 yearlings and 5,000 fry. Storr Lochs will be re-stocked again in the autumn, and for the first time, the reservoir at Loch Sloy is shortly to be re-stocked with 10,000 yearling trout.

Automatic fish counters are in use at Pitlochry and Clunie, and checking by visual observation have shown them to be remarkably accurate. Over the past year the Board has evolved an experimental electric screen to divert descending smolts away from the head race intake at Tummel Bridge; this showed some degree of diversion, but will need further experiment before it can be said to be satisfactory. The electric screen at Loch Poulary has already been mentioned, and was completely successful; more work will be done along these lines. As regards the opening up of new waters, obstructions at the Falls of Conon are to be eased and a fish pass provided through Luichart dam—improvements that will enable salmon to ascend to the upper spawning grounds in the Bran for the first time. Stocking of the Bran was begun in 1953, when 200,000 salmon fry were released. There are already fingerlings under observation. In the same way the fish pass on the Lochy will open up this river to salmon, and provide valuable new spawning grounds.

The clearing of predatory fish has been another important part of this work, and is, indeed, complementary to the re-stocking programme. One example will provide some idea of the excellent work in progress. In 1952 and again in 1953, a team of three Irish fishermen from Lough Neagh undertook the clearance of Loch Luichart, Loch a' Chuilin, and Loch Achanalt in the Conon Valley. Using hand nets, perch traps, and lough-type sweep nets, they cleaned 1,306 pike in 1952 and 2,264 in 1953. The higher number in 1953 consisted largely of smaller pike only a few inches long. In the first three months of 1952 the average weight of the pike taken was 8·3 lb. In 1953 the average weight dropped to 2·5 lb. In 1952 over 30 pike weighed more than 12 lb. each, but by 1953 a considerable number of trout weighing ½ to 1½ lb. were taken from an area where, in 1952, only pike were found. In 1953 only one pike was caught weighing more than 12 lb.

Perch cleared numbered 21,329 in 1952 and 8,205 in 1953, although the average weight rose from 4 to 5 oz. in 1952 to 5 to 6 oz. in 1953.

In the first year there was a very successful clearance of eels, but this was not repeated in 1953 to avoid interference with the main objective. While this was the main area for clearance of predatory fish the Board's officials assisted in clearing several other areas.

Just how important and valuable all this work may be remains to be demonstrated in terms of the expanded fish population in the waters involved. Even now, however, some of the projects are bearing fruit, and suggest that this co-operation between hydro-electric and fishing interests may develop into a major factor in the continuity and expansion of an important Scottish sport industry.

From page 215

rock, amounted to 328,000 cu. yard, and 223,000 cu. yard of concrete were placed, the best month's progress being 13,500 cu. yard. 50,000 tons of cement were used. About £600,000 worth of construction plant was employed, the great bulk of which was ordered and shipped out within the first few months of the contract. All this had to be transported 750 miles up from the coast and assembled on the site. In view of the shipping delays, accurate forecasts had to be made of requirements for plant for six months ahead and a large quantity of spares had to be carried. Very well equipped workshops were maintained as the local facilities were poor and the work had to be self-contained in this respect.

The European staff and workmen numbered some 300, whilst 150 Asians and 2,300 Africans were employed on the less skilled work.

Lake Victoria is an essential link in the control of the Nile and in addition to the dvelopment of power at Owen Falls, the dam has been built to sufficient height to enable full control of the river to be exercised with future benefit to the Nile valley.

(To be continued)

Owen Falls Turbines. We have been requested by Boving & Co. Ltd. to state that the photograph which appeared in their advertisement on the front cover of our May issue of one of the turbines they have supplied to the Owen Falls station was reproduced by courtesy of the Uganda Electricity Board.

Fig. 10. Nangal dam from downstream. The depression in the mountains in the background is the Bhakra gorge

India's Bhakra-Nangal Project

An Indian correspondent describes a major scheme on the Sutlej river in the Punjab which will provide 400MW of firm power and irrigate six million acres.

PART TWO

Power Plants at Bhakra

Two power plants will eventually be constructed downstream of the Bhakra dam. Power Plant I is located on the left river bank. The second plant was first proposed to be built underground in the right abutment, but this idea has been given up. The right side plant will be a future installation. Power will be generated by six 90 MW units in Power Plant I and by four similar units in Power Plant II.

An electrical load survey has been carried out in the region to be served by the Bhakra Nangal project. It has revealed that the present load of 58 MW in the areas served by the Uhl river power station at Jogindernagar and the Delhi State Electricity Board will increase to 125 MW in 1958-59 and to 170 MW in 1964-65. To meet this demand, 70 MW will be available from the Nangal stations from 1954 onwards. This power will be supplemented by the first generating unit at the Bhakra power plant.

The total generation on the integrated Bhakra-Nangal grid will be 400 MW of firm power, provided by the ten 90 MW units at the Bhakra dam in addition to six 24 MW units on the Nangal canal. The operating head of the Bhakra dam power plants will range between 520 ft. at full reservoir level to 265 ft. at the lowest reservoir level during the years when the reservoir does not fill and irrigation requirements are given priority.

Power Plant I has its centreline about 580 ft. downstream from and parallel to the axis of the dam, with the outer end of the building forming part of the left training wall of the spillway. Besides accommodating the six generating units it will have a service bay, control room, office and machine shop. This plant

will be the largest in South East Asia, and one of the world's biggest hydro-electric plants after the Hoover, Grand Coulee and Shipshaw in the United States.

Penstocks

Ten main steel penstocks, 15 ft. in diameter, will be embedded in the body of the dam. They will have control gates and trashracks on the upstream face. Six of these penstocks will be installed in the left abutment section for connection with the Power Plant I and four in the right abutment for the future Power Plant II.

Since the second power plant will not come into existence for some time, it has not been considered wise to invest money in steel and excavation for penstocks, some of which may not be needed for several decades. The penstocks for the future units will therefore extend only up to the first longitudinal contraction joint in the body of the dam. Some changes have also been made in the alignment of these penstocks, effecting a saving of over Rs. 10 million (£750,000) in the initial expenditure and Rs. 450,000 (£33,750) of annual interest.

Communications and Township

To facilitate the economic transportation of construction equipment and material to the site of work, the Bhakra dam site has been made accessible by broad-gauge (5 ft. 6 in.) railway and a first-class highway.

The Nangal-Bhakra hill road and the railway line necessitated nearly 50 culverts and many major works including one tunnel 1,100 ft. long costing nearly Rs. 850,000 (£64,000).

A township has been built at Nangal containing nearly 200 bungalows, over 1,000 quarters for the staff and over 2,000 quarters for the workmen. There are two rest houses, two big office buildings, a concrete testing laboratory and large workshops. There is a 100-bed hospital, schools for girls and boys, post and telegraph offices, a sub-treasury and a police station.

The Nangal Dam

This dam is located eight miles downstream of Bhakra, and except for the installation of gates and gearing, its construction is complete. The Nangal dam is to perform three functions:—

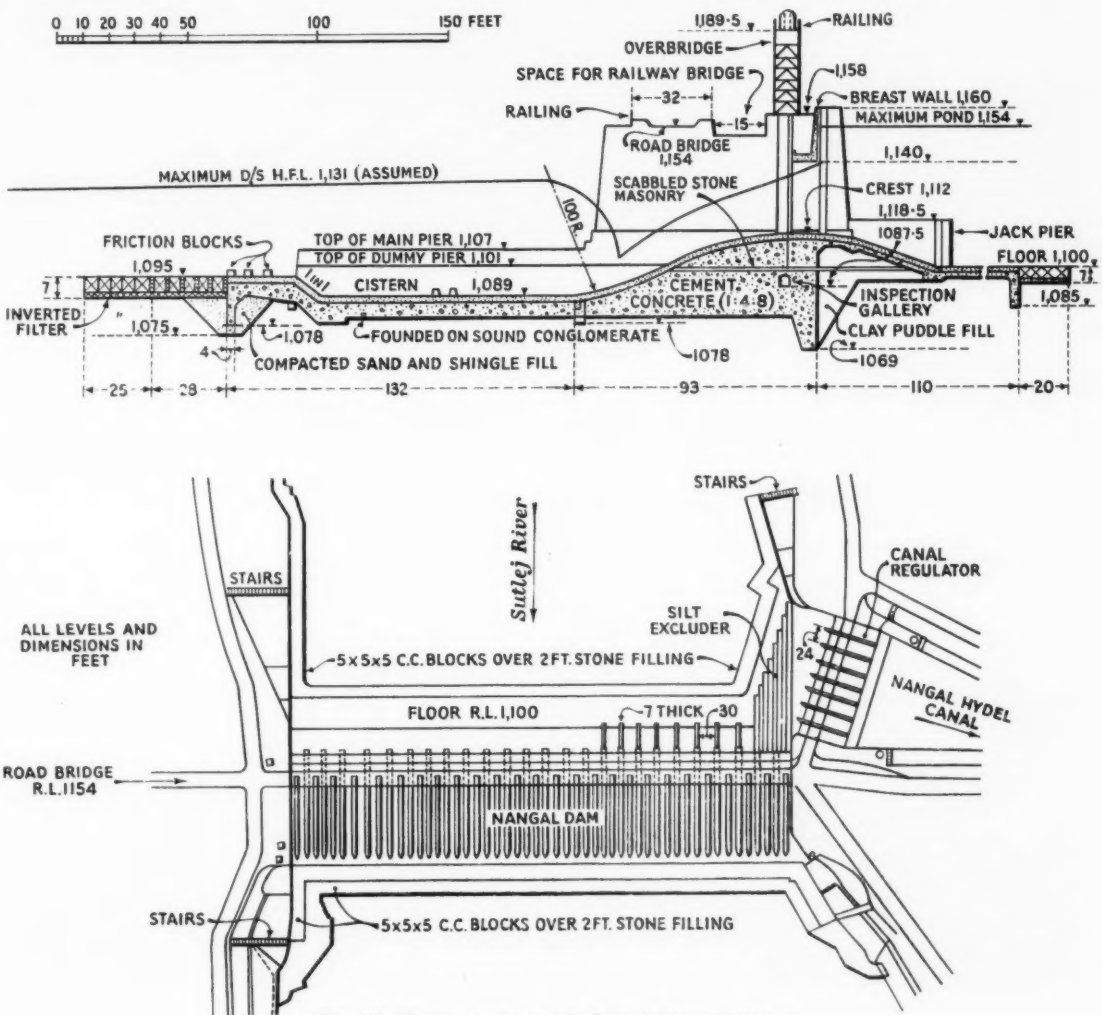


Fig. 11. Cross section and plan of Nangal dam

Fig. 12. Excavations in progress for Nangal dam. Note the high-level track in the background for hauling out the muck and the pump discharges in the foreground

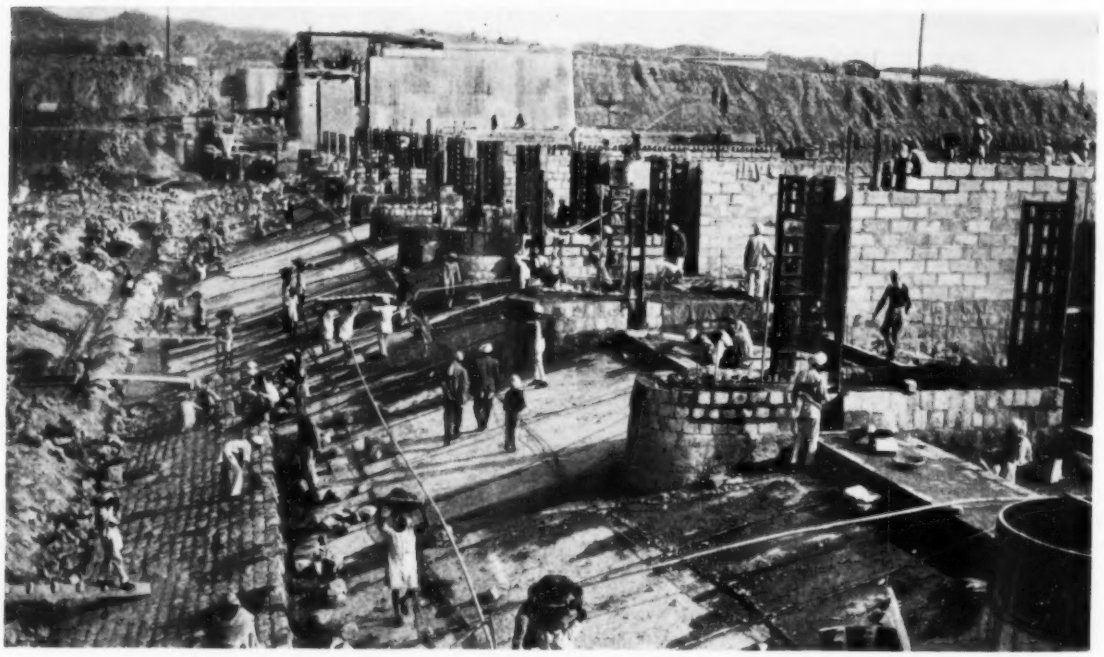


Fig. 13. Stone masonry being placed in the construction of Nangal dam

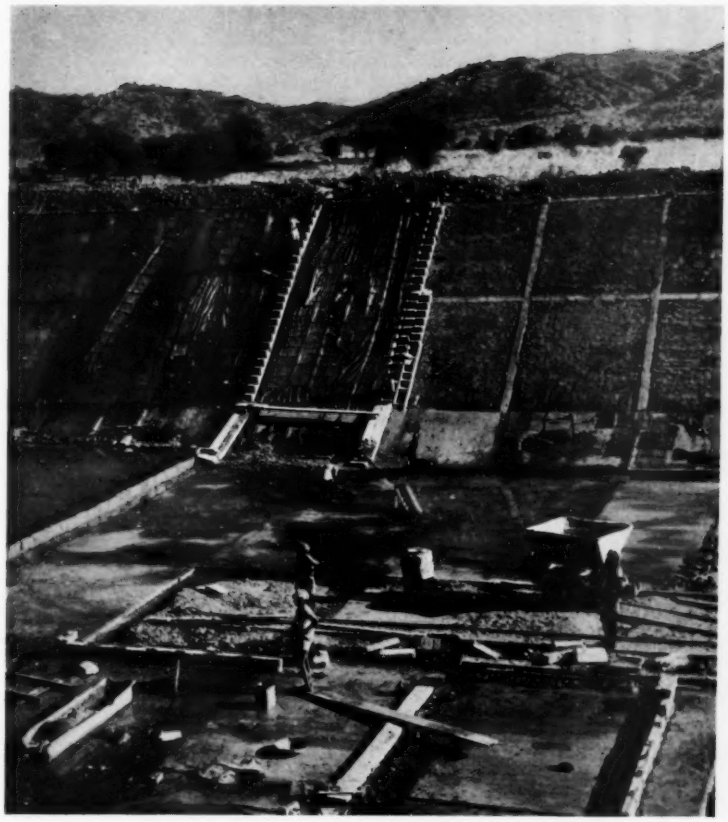


Fig. 14. Lining operations on the Nangal-Hydel canal

(a) It will direct waters released from Bhakra into the Nangal Hydel channel, for the purposes of irrigation and power generation.

(b) It will provide a balancing reservoir for smoothing the diurnal and weekly fluctuations of the Bhakra power station so as to provide a non-fluctuating supply for irrigation without wastage of water.

(c) It will provide a storage reservoir to cater for the variable discharge required to take up the daily and the weekly load factor of the Nangal power stations during the pre-Bhakra stage.

The dam can be divided into the three following main parts:—

(i) The dam proper consisting of 26 bays of 30 ft. span each separated by 7 ft. thick piers.

(ii) A head regulator for the Nangal canal consisting of eight bays of 24 ft. span each.

(iii) A shingle excluder in front of the head regulator covering two bays of the dam and consisting of six tunnels.

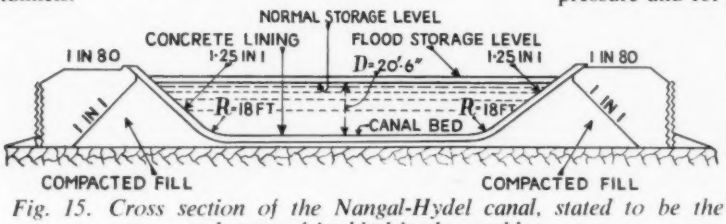


Fig. 15. Cross section of the Nangal-Hydel canal, stated to be the largest of its kind in the world

The maximum height of the dam from the deepest foundation level to the top of the breast wall is 95 ft., and the maximum hydraulic head across the dam will be 53 ft. An arterial road bridge has been constructed across the dam, the decking consisting of precast reinforced tee beams covered with a 4 in. reinforced-concrete mattress and a 3 in. wearing coat.

The head regulator has been designed as a headless flume, so that maximum drawdown is obtained from the storage reservoir upstream of the dam. Its shape has received particular attention, so that the canal can be fed with the minimum disturbance of flow. This reduces the chances of travel of shingle and sand into the canal.

The shingle excluder has been provided as a further safeguard, and in the first two bays of the dam where this excluder is located the crest has been kept 4 ft. lower than the rest. The shingle excluder consists of six two-storey tunnels, and the design is believed to be the first of its kind. It gives complete control over the quantity of the water drawn from the upper or the lower layer as found suitable in actual practice.

Dam Foundation

Exploration showed the existence of conglomerate strata near the proposed foundation, but the level was not uniform. The design therefore provided for the upstream curtain wall to pierce the conglomerate by at least 5 ft. depth in order to cut off the seepage and thereby minimise the uplift pressure under the dam. For safety, however, the downstream floor thickness has been provided to withstand the full uplift pressure. In the calculations advantage has been taken of the weight of piers. Dummy piers have been provided in order to add to the weight of the downstream floor and for regularising the flow of water.

A system of sub-foundation drainage coupled with pressure-relief pipes has been installed, and an important innovation is the provision of the inspection and the grouting gallery. This will enable engineers to keep a watch on the percolation of water through the dam and will provide means for the release of pressure and for grouting.

The river level upstream of the dam is to be controlled by counter-balancing Stoney gates. A big saving has been made in the cost of steel by the provision of breast walls above the tops of the gates.

In the construction of this dam, scientific batching of the aggregate and mixing of concrete was introduced in the Punjab for the first

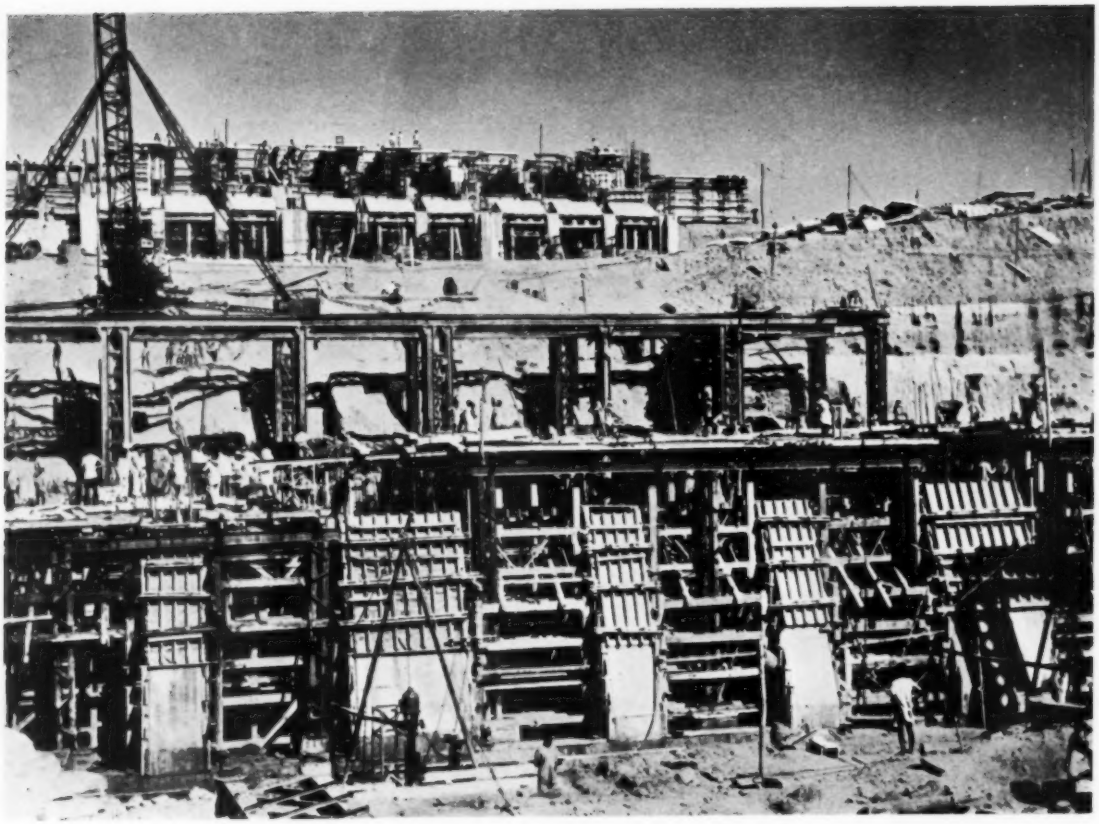


Fig. 16. Gangowal power house under construction

time. Furthermore, a trestle bridge was laid in the area to be concreted, on which concrete buckets were hauled by improvised locomotives. The mixers added to the speed of construction and ensured uniformity in the quality of the concrete. The maximum progress of concrete achieved in one day was 52,152 cu. ft.

Programme of Power Development

Commencing from about the middle of 1954, the Bhakra-Nangal project will start generating power in Power House No. 1 on the Nangal canal (Gangowal). This power house is fast nearing completion, and two 24 MW Westinghouse units are already on site. The erection of these units is now in progress, and final touches are being given to the structure. The scroll cases for the runners have been manufactured for the first time in India, at the Government Central Workshop, Amritsar. Similarly, the penstocks for these generating sets have been

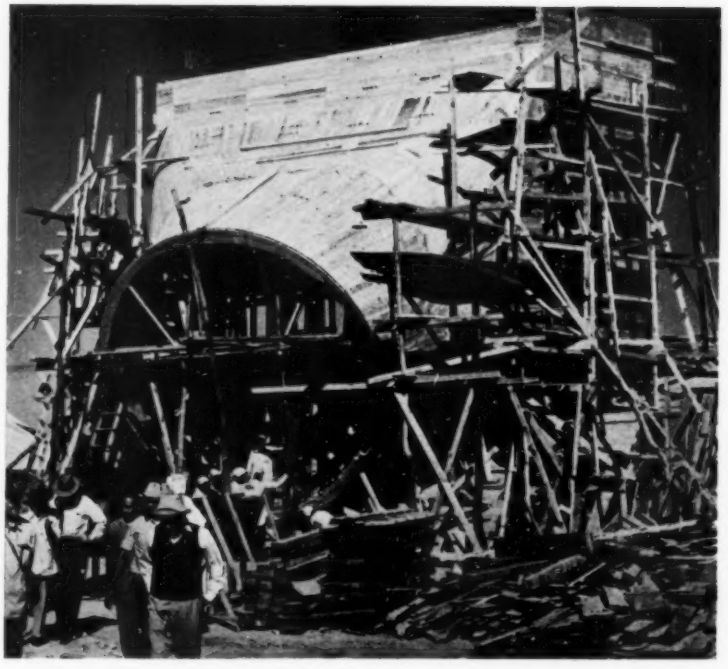


Fig. 17. Draught-tube shuttering made of deodar timber

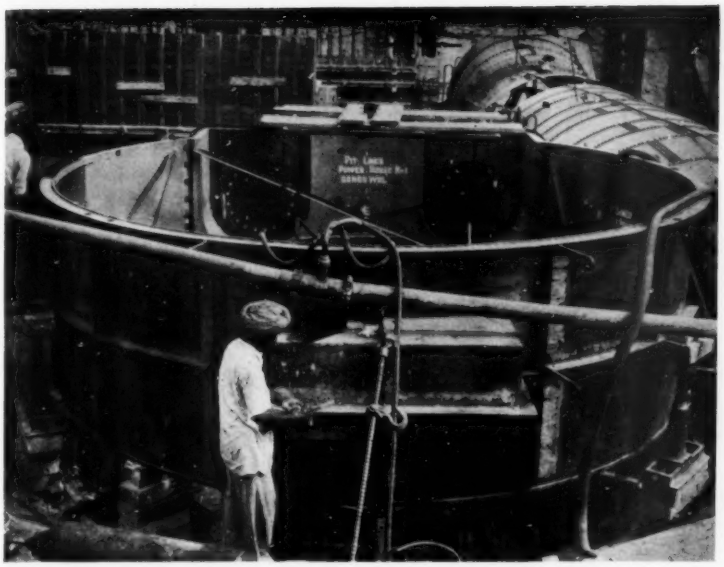


Fig. 18. Erection of pit liner in Gangowal power house

fabricated at the departmental workshops at Nangal.

As regards transmission and distribution of the power, steel towers are being erected on the sections Gangowal to Ludhiana for linking with the Uhl river grid. Similarly the line from Nangal to Delhi via Ambala and Panipat is being completed. The working of the integrated Uhl, Bhakra-Nangal and Delhi generation systems has been experimentally investigated at the Indian Institute of Science at Bangalore, which is the only laboratory in the East for such work.

The project includes the installation of 74 grid stations in which voltages will range between 33 to 220 kv. About 2,500 miles of high and extra-high voltage transmission lines will be constructed in the range 11 to 220 kV. Electrification of about 86 new towns is envisaged in the project, besides conversion of 25 to 30 towns which are at present supplied by thermal plants. A big block of power is to be utilised at Delhi which is at present served by the local thermal station. There is provision in the project for electrification of rural areas. Nearly 3,000 million kWh of electrical energy will be available.

Plans are being prepared by co-operation between the Government and private interests for utilisation of the power from the Bhakra-Nangal project on light and heavy industries. It is anticipated by the planners of the project that in addition to the load of lights and fans there will be modern labour-saving appliances such as cooking ranges, washing, drying and ironing machines, refrigerators, heaters and boilers. For drinking and domestic water supply, electricity will be harnessed for operating tube wells and pumps. Already, in co-operation with TCA, the Punjab are sinking about 400 tube wells. It is being planned that each village community may have its own flour and rice mills, its own sugar refinery, oil extractor, dehydrator and freezing locker.

Delhi State will provide a load expected to grow to 40 MW in the course of the first ten years. The main development of power, however, will come through heavy industries. These include cotton and woollen textiles, paper, cement, oils, soap, flour and starch, cold storage and food preservation. Whereas there is enthusiasm for such development, and ample justification for the Bhakra-Nangal scheme, the more conservative sections in the country are emphasising the need for caution in any too ambitious expectations of rapid power development.

Fig. 19. Nangal township construction colony and administrative headquarters

Holman Silver Three Handril

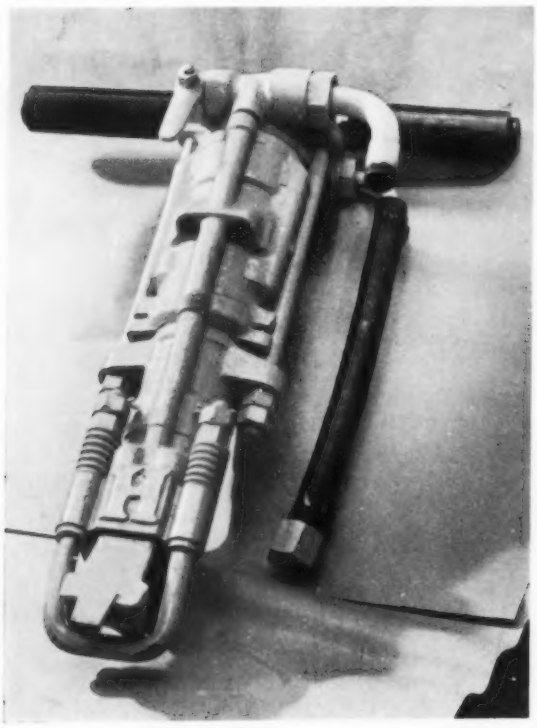


Fig. 1. Holman Silver Three Handril

Fig. 2. The Handril in use with an airleg

We recently had the opportunity of seeing in operation the latest of the range of high-speed medium-weight drills for use with tungsten-carbide bits placed on the market by Holman Bros. Ltd., Camborne. It is known as the Silver Three Handril, and as will be seen from the accompanying illustrations, is used in conjunction with a Holman airleg. It can be supplied for dry or wet drilling, the respective weights being 53 lb. and 55 lb. The drill is designed for high speed and lightness of blow, and has a cylinder bore of 3 in. and a piston stroke of $1\frac{15}{16}$ in. The valve has a short travel and is not subject to peripheral wear. Rotation, which is claimed to be positive in all types of ground, is effected by a four-pawl twist bar and ratchet, the twist bar having six splines and the piston eight.

Lubrication is effected by a line oiler, but instead of the oil that passes through the rear of the machine escaping with the exhaust air, most of it is collected in special chambers and fed to points on the periphery of the chuck.

The throttle has a "blowing" position, in addition to the usual "on" and "off" positions, in which live air is passed down the drill steel to clear the hole.

The machine can be supplied with either a bar or a D handle; it can take $\frac{7}{8}$ in. or 1 in. hexagon shanks, and a latch-type retainer is fitted.

The design of the Silver Three has been finalised after thorough tests on prototypes in the company's own mine and by various customers. We understand that a usual drilling speed in granite with a $1\frac{3}{4}$ in. bit is 15 in. per minute.

G.E.C. 33 kV On-Load Tapping Switch

The range of on-load tapping switches manufactured by The General Electric Co. Ltd., Birmingham, England, has recently been augmented by the introduction of a new unit, type O.L. 33/300/19 (N), for use on transformers with 33 kV windings. This switch (Fig. 1) has a current-carrying capacity of 300 A and, by using the long-established system embodying a centre-tapped reactor, provides a maximum of 19 voltage ratios with ten tappings on the winding. The minimum step voltage recommended is 1·25 per cent.

The switch is normally arranged for remote push-button control, but local pushbuttons can also be accommodated, while automatic control can be provided through the medium of a voltage-regulating relay. Facilities for manual operation for use in cases of emergency and during servicing operations are always included. For supervisory control, auxiliary switches can be fitted to give remote indication. If two or more units are to work in parallel, further auxiliary switches can be provided to energise an

Fig. 1. G.E.C. on-load tapping switch

out-of-step relay which, in turn, operates an alarm and locks out the control circuit if the transformers are out of step.

The complete tapping switch is assembled as a self-contained unit and is attached to the transformer by a bolted flange. The unit is divided into three compartments; one houses the three-phase selector switch (Fig. 2) which serves solely to select the required tapping, no power being broken by the switch contacts; a second houses the cam-operated diverter switches which are of the single-break type and serve to interrupt the power circuit; the third contains the intermittent gear and driving mechanism.

The selector and diverter compartments are oil-filled, the former being connected to the main transformer conservator, while the latter has a free oil level. The centre-tapped reactor is mounted inside the transformer tank.

In the assembly of the tapping switch, full use is made of universal joints between phases and between the switch and its operating mechanism. The intermittent gear comprises two maltese-cross gears, one for operating the selector switches and the other for the diverters, and is coupled to the driving mechanism by duplex roller chain. The intermittent gear not only governs the timing of the operations of the selector and diverter switches, but also serves to lock these parts in position at the end of each tap change. The sequence of operation is such that there is no possibility of the selectors opening under load.

The driving mechanism comprises three sections—the driving and gear-reduction unit, the manual operation unit, and the auxiliary control switch unit, and is arranged for easy servicing. Insertion of a removable handle for manual operation automatically disconnects the driving motor both mechanically and electrically.

The auxiliary control switches are mounted on a Bakelised paper panel in such a way that all contacts, terminals and wiring are readily accessible. Limit switches prevent overrunning the end tapping positions, and, in addition, a limit stop is fitted to arrest the motor drive should the limit switches fail to operate. A local tap-position indicator and an operation counter are also included in the assembly.

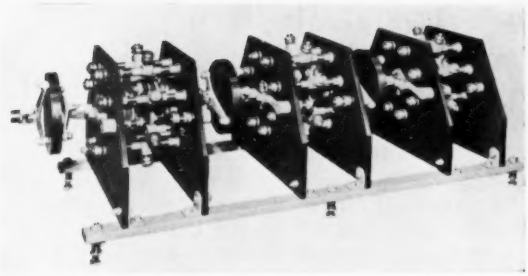


Fig. 2. The three-phase selector

The centre-tapped reactor is fully rated, so that, in the event of a tap change not being completed, the transformer may safely be left in circuit until the fault has been corrected. Should the fault have been caused by a failure in the supply to the motor, the switch will automatically revert to a "home" position when the supply is restored.

Errochty Alternator

The accompanying illustration shows the vertical-shaft alternator which the General Electric Co. Ltd. have constructed for the Errochty power station of the North of Scotland Hydro-Electric Board. This machine, which is shown on the testbed at the Witton Engineering Works, is the second of the three alternators, of the same rating, to be built for this station. It has an output of 25 MW at 11 kV and is to be driven at 428 r.p.m. by a Boving turbine.

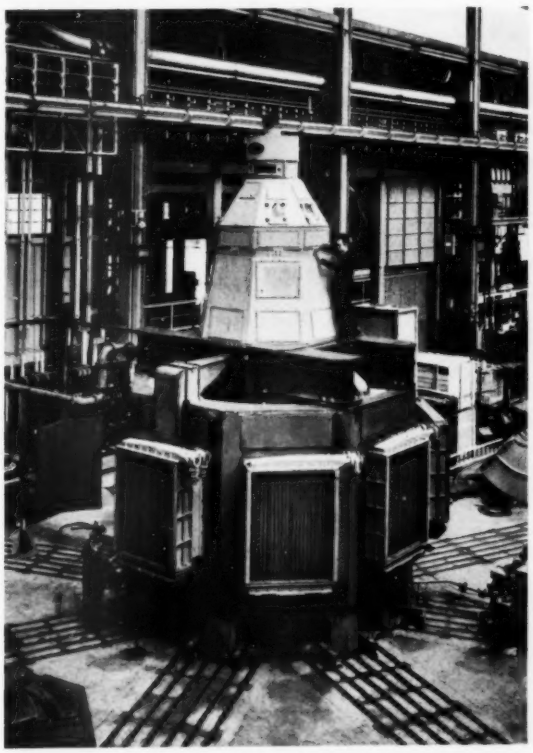
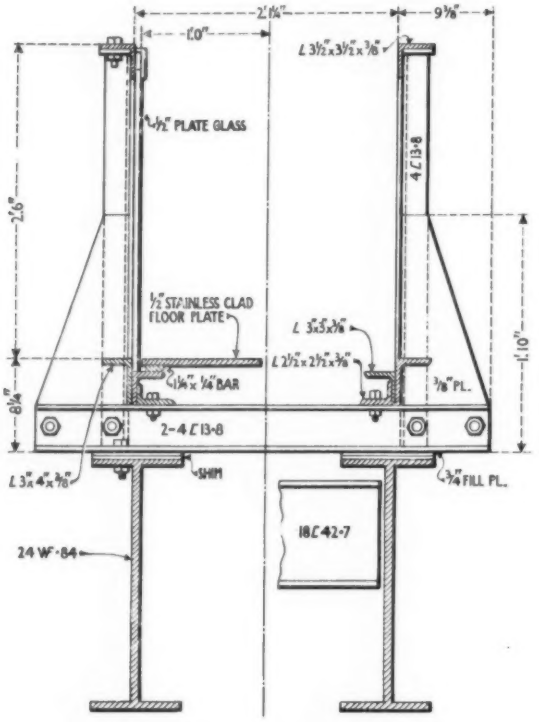


Fig. 1. The Errochty 25 MW 11 kV alternator

Abstracts from the World Technical Press

An Improved Research Flume

A description is given of an unusually rigid flume with glass walls for the study of channel hydraulics, which is being installed in the Illinois State Water Survey's Laboratory in Urbana. The 58 ft. 10 in.



Details of test-section cross frame

flume is designed to deflect only 0·035 in. under full load. Because of this unusual rigidity, measurements of the depth of the flowing water by point-gauge methods will not require correction for flume deflection. Variance in point-gauge measurements is estimated to be of the same order of magnitude as the deflection; at full depth, the maximum possible error in depth measurement would amount to 0·25 per cent. To meet the deflection standard the tilting flume is supported by two 60 ft. 24 WF 84 beams. Structural details of a typical test-section cross frame are shown in the appended diagram. (*Engineering News-Record*, Vol. 151, No. 26, 24.12.53, p. 48, 1 f.)

New Pumped-Storage Project in U.S.

From further details of the proposed pumped-storage power project to serve western New York State as well as Pennsylvania and Ohio, as disclosed by the Energy Accumulation and Exchange Corporation of New York City recently, it appears that water for the project is to be pumped from Lake Erie to an elevated reservoir situated about four miles south of the lake and about midway between Dunkirk and Chautauqua Lake. The reservoir is projected to be about six miles long and to have a storage capacity of 500,000 acre-feet, created by two dams, one 90 ft. high and 6,000 ft. long, and the other 100 ft. high and 7,200 ft. long. The maximum surface elevation would be 1,392 ft., or 820 ft. above Lake Erie, and a drawdown of about 70 ft. would be possible. An initial installation of five 80,000 kW pump-turbine units is contemplated at an estimated cost of $60 million for the pumping plant, penstocks and reservoir. There would be a weekly cycle of operation, involving filling the reservoir during the night and at weekends when industrial load on the Niagara network is low, and drawing it down gradually at peak-load periods during the following week. This, it is stated, would enable the existing power companies to make better use of the large amount of flow at Niagara that can be used for power generation during periods of low demand. (*Engineering News-Record*, Vol. 152, No. 1, Jan. 7, 1954, p. 25.)

French Colonial Developments

This issue of *Travaux* is devoted to electric developments in the French Colonies, and contains a number of articles of special interest among which we should like to mention the following:—

"General trends of electric developments in Overseas France," by E. Crouzet, Inspector General of Public Works in Overseas France, p. 61, 2 pp.;

"Overseas Electrification, its present progress and future prospects," by A Antoine, Inspector General of Electricité de France, p. 65/66;

"Problems confronting Contractors in French Colonial Developments," by L Bourrelles, p. 67, 3 pp.;

"Electricial Equipment in Overseas Territories," contributed by the French Association of Manufacturing Electrical Engineers, p. 73/74, 3 ff.;

"Teachings from the construction of hydro-electric plants in Black Africa," by D. Migny, Overseas Research Engineer, E.D.F., pp. 81/82, 2 ff.;

"The Grandes Chutes Development," by F. Lesguillons, Director General of "Energie Electrique de la Côte-d'Ivoire, p. 104, 3 pp., 4 ff.;

"The Edéa hydro-electric plant, Edéa-Duala transmission line, and Bassa thermal plant," by A. Arland, Director General of Cameron Electrical Energy, p. 107, 14 pp., 24 ff.;

"Electrification Achievements in French Equatorial Africa," contributed by Energie Electrique d'A.E.F., p. 121, 9 pp., 16 ff.;

"Madagascar Hydroelectric Developments," by Société d'Energie de Madagascar, p. 130, 2 pp., 2 ff (*Travaux*, Vol. 38, No. 232, February 1954).

Spillways with Fan-Shaped Outlets

Model tests carried out with various designs of spillway channels operating in conjunction with earth or rockfill dams are described and discussed. Fig. 1 shows the general layout of the plant instanced which comprises an underground powerhouse excavated in the rock on the right bank of the river, and a rockfill dam flanked on either side by a flood-discharge channel evacuating 5,500 cu.m. per second at a height of 12 m. above the maximum high-water level of the river. Fig. 2 shows the six various patterns of spillway tested.

While the general model of the plant was made at the scale of 1/60, the spillway models were constructed on a scale of 1/180. The main purpose of the tests was to ascertain the most favourable type of spillway outlet from the viewpoint of river-bed erosion and flow perturbation.

Tests with pattern 1, which gradually decreases in width towards the outlet, established that the discharge reached the river in a highly concentrated jet likely to cause substantial erosion; in addition, as the jet left the spillway diagonally to the river, it hit the opposite bank with great force, especially with one channel in operation, causing high surges in the river. In pattern 2, the edge at the bottom of the outlet is almost parallel to the river, and the outlet itself almost twice as wide as pattern 1; however, owing to centrifugal force, the water flows along the left wall of the channel at a higher elevation than along the inner wall. In pattern 3, there is a greater dispersion of the jet but the effect of centrifugal force is still conspicuous. Owing to a contraction of the channel at mid-length, the dispersion of the jet in No. 4 is still more pronounced; a further improvement was introduced in pattern 5 by straightening out, from the downstream edge upwards, almost a third of the whole length of the channel on the left side. The most favourable solution proved to be pattern 6, in which the downstream left side of the outlet slightly deflects outwards, thus producing an even greater diffuser effect, and a thin and broad jet which entrains a considerable amount of air into the river. The superiority of this pattern appears clearly from the photographic illustrations accompanying the original report, and was fully confirmed when a new spillway model at the scale of 1/60 was fitted on to the general model of the plant. The force with which the water struck against the banks proved to be considerably less with pattern 6 than with pattern 1. An attempt to reduce still more the width of the waist in model No. 6 produced negative results, the cross-section of the jet being too narrow and giving rise to a hydraulic jump. All these tests were effected at the Laboratory of Hydraulics of the Royal Institute of Technology, Stockholm, Sweden. (Professor Dr. B. Hellstrom, *La Houille Blanche*, Vol. 8, No. 6, December 1953, p. 873, 8 pp., 14 ff.).

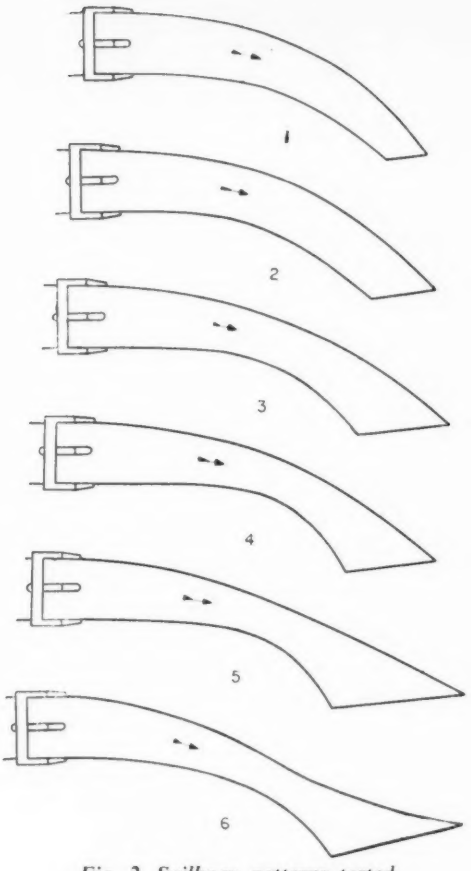


Fig. 2. Spillway patterns tested

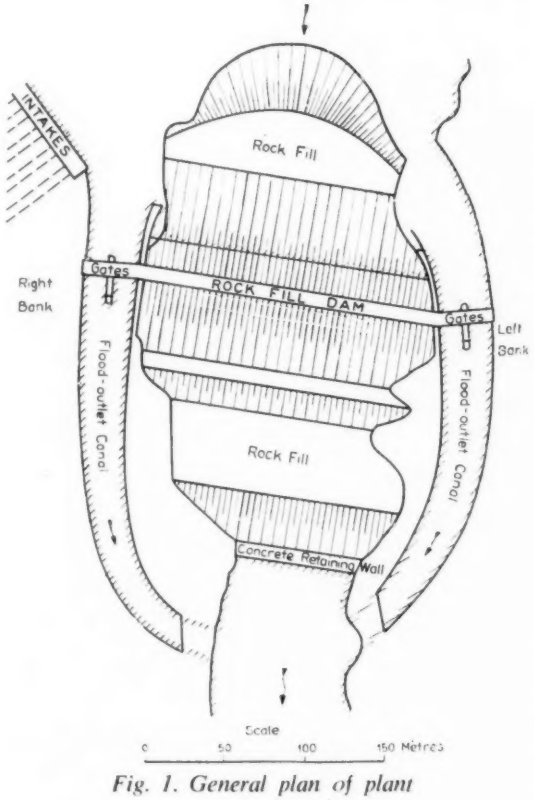


Fig. 1. General plan of plant

New Portable Crushing Plant

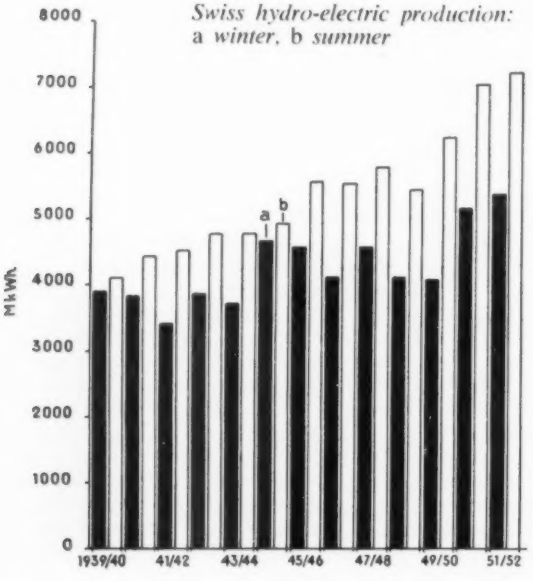
A short description is given of the "All American 77," a new high-capacity crushing and screening plant that is completely mobile for road transportation. Hourly production, as reported from recent field tests, exceeds 350 tons of $\frac{3}{4}$ in. or smaller aggregate; the high productivity is attributed to the straight flow of material in the plant, supported by an oversize star-gear roll crusher, a combination which, it is claimed, rules out bottlenecks, bypassing operations and double scalping. This 36 × 22 in. unit is designed to reduce $2\frac{1}{2}$ in. material to $\frac{3}{4}$ in. aggregate, and thereby relieve the 10 × 36 in. jaw crusher of preparing material to $1\frac{3}{4}$ in. for reduction in a smaller set of rolls. Similarly, a 4 × 12 ft. $2\frac{1}{2}$-deck vibrating

screen affords substantial screening area and is considered to provide a better segregation of aggregates. The conveyor belts are 30 in. wide to match the high output of the rest of the plant. From a platform affording a full view of the whole unit, the operator controls all crushing and screening operations, as well as the hydraulic mechanism which raises the vibrating screen to and from travel position. A further hand control enables considerable time and effort to be saved in setting up and dismantling the plant. The plant is actuated by a side-mounted power unit through a spline shaft, and power is distributed by guarded V-belt drives wherever possible. The whole unit is carried by an electrically welded goose-necked trailer provided with a fifth wheel plate and pin on the front, and two axles and equalizer on the rear. A folding delivery conveyor allows room for the tractor cab while travelling. The road weight of the unit is 64,000 lb. (*Engineering News-Record*, Vol. 151, No. 22, Nov. 26, 1953, p 77, 2 ff.).

Swiss Water-Power Resources

A comprehensive survey and quantitative assessment of Swiss water-power resources is given. This study is divided into four sections, viz. plants in operation on January 1, 1947; plants commissioned since January 1947; utilisable resources for which development projects have reached an advanced stage; utilisable resources for which projects or preliminary studies have been carried out but which are still awaiting clarification from the technical, economic, administrative or legal aspect. Separate figures are given in all sections for run-of-the-river and storage plants, as well as for public-utility developments, and developments initiated by railways and industrial concerns.

Plants in operation on January 1, 1947, were producing 10,450 million kWh, and an increase of 6,788 million kWh was expected from plants in course of construction. The production of the two classes of utilisable resources listed is estimated at 5,227 and 6,000 million kWh respectively, so that the aggregate possible production of all Swiss hydro-electric developments, present and future, would be 28,500 million kWh. (*Wasser- und Energiewirtschaft*, Vol. 45, No. 11, Nov. 1953, p. 232, 10 pp., 1 f., 25 tables).



Swiss hydro-electric production: a *winter*, b *summer*

Fish versus Water Power

A controversy in which German anglers seem to have branded the Kaplan turbine as the fish killer in chief still appears to remain undecided. The report under review is based on inquiries made by the author since the first Kaplan turbines were put into commission, about 25 years ago. In the Ruhr, no injured or decimated fish has ever been found in the tailraces, although observation is made easy. As to turbine intakes, the only fish which happened to be pressed against the screens, had either been injured previously, most likely by ship propellers, or were disabled by spawning disorders. Highly interesting was the observation made at the Hengstey pumped-storage plant; when the secondary reservoir, 170 m. above the Hengstey lake, was emptied in 1949 many sizeable fish up to 15 lb. weight were caught, but eels were conspicuously absent. The question arises how did these fish, chiefly pike, manage to pass unscathed through the machines, in which there is a sudden pressure increase of almost 250 lb. per sq. in.? It can only be assumed that, at the time of their journey to the upper reservoir, they were still at the fry or spawn stage.

On the other hand, plants equipped with Francis turbines and using screens with 20-mm meshes report that, in the autumn, their staff caught a glut of fish, especially eels, which had got jammed in the meshes. It would thus appear that fine screens are more harmful to fish than coarse ones, whatever the turbine system in operation may be. The author's experience is upheld by observations made elsewhere, particularly in Southern Germany, and is summarised as follows:—

1. The damage alleged to have been caused by water-power installations is practically restricted to eels.

2. There has been up to now no irrefutable evidence that eels have been torn to pieces by Kaplan turbines.

3. The extent of the damage claimed by anglers to be attributable to water-power plants varies between 10 and 30 per cent.

4. None of the tests made so far has given unreserved support to the angler's claims, and it is not expected that further tests will supply proofs unless fish are stopped from entering the turbines by nets fixed at the downstream end of the draught tubes.

According to this report no experiments have yet been made in Germany with pulsating electric screens. (Dipl. Ing. Hugo Franz, *Die Wasserwirtschaft*, Vol. 44, No. 3, February 1954, pp. 127/128).

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

FOR SALE—"Cameron" Heavy Gear, belt driven 3 plunger pump, with 7 in. plungers and 9½ in. stroke.—M. Bloomfield, Debenham, Suffolk.